THE PSYCHOLOGY OF LEARNING

The Psychology of Learning

An Advance Text in Educational Psychology

By
William Henry Pyle
University of Missouri

BALTIMORE
WARWICK & YORK, Inc.
1921

CONTENTS.

PREFACE.

In this book I have tried to state every thing that is known about learning. All the experimental work that throws any light on the nature of learning has been carefully examined, and in the light of the experimental results I have endeavored to give the present impartial verdict of educational psychology. Throughout, I have tried to keep within the facts. When the evidence does not warrant a definite conclusion, I say so. The few cases of theory and speculation are plainly labeled as such. The practical significance to the teacher of the facts discussed is pointed out.

The successful use of this book will depend upon two things: first, experimentation; and second, application. Educational psychology is an experimental science. All its facts come from experimentation and careful observation. These facts, whenever possible, should be demonstrated or illustrated by class room demonstrations and experiments, or by experiments and observations outside the class room. Directions for demonstrations will be found throughout the book, but the teacher must use his own ingenuity in adapting the experiments to his needs and in devising others. And always, the facts must be carried over to their practical application. The students must see the source of the facts and the use of the facts in teaching. The book contains many tables and figures. The mastery of the book will depend upon an understanding of the meaning and significance of the tables and graphs.

W. H. P.

CHAPTER I.

THE NATURE OF LEARNING

What is learning? What are its results? After we have learned, in what way are we different from what we were before? After a child has been in school for a few years, he can read, write, spell, and perform various other acts. He also knows that Columbus discovered America, that George Washington was our first president; he knows the name of his country, of his state, and of our nation; he knows many other facts in geography, history, arithmetic, and the other branches of study, and many hundreds of other facts that he has not learned at school and that may not be in any organised branch of study. The difference in the child that has come from learning, then, is that he can do things and knows things that he could not do and did not know before. He has knowledge and habits that he did not possess before. The results of learning, therefore, are knowledge and habits. And from the point of view of its results, learning may be defined as the process of forming habits and acquiring knowledge. This, however, is but a superficial statement of the facts. We must know the nature of knowledge and of habits before we can understand the nature of learning.

Habits.—A habit is an act following with more or less regularity upon the presentation of a definite stimulus, to which it has become coupled through experience. Writing, reading, and spelling are such

acts. In writing, the stimulus is the idea of the word to be written. The movements of the arm and hand in writing the word constitute the response. In reading, the stimulus is the perception of the printed or written characters. The response, in oral reading, is the movement of the various organs of speech. In spelling, the stimulus is the idea of the word to be spelled. The response is the movements of the hand and arm in writing the word, or in oral spelling, the movements of the organs of speech as in reading. In all habits, the stimulus is either a perception or an idea. The response is muscular movement. When we say the stimulus is a perception or idea, we mean the cortical excitation which is the physiological correlate of the idea or perception. Throughout this book we shall speak of ideas in this way without committing ourselves to the doubtful theory of interactionism. We believe that in a scientific psychology mental processes must not be used as elements in a causal series. When we so use them it is for simplicity of statement, and with the understanding that the cause indicated is the brain action and not the mental process.

Knowledge.—Knowledge is also a special form of organised experience. Suppose, for example, I am sitting at my desk writing and become cold. The idea comes to me that coal should be put into the furnace. I *know* that if coal is put into the furnace and the draft of the furnace is opened, the room will become warm and I will become warm. This knowledge is the result of experience. Just as in the case of habit, a definite response—action—follows upon a definite stimulus, so also in the case of knowledge, an *idea* follows upon another *idea* or upon a *perception*. In both cases, the

definite sequence is due to experience, and usually to repeated experience. At any rate, the repetition of the experience makes the sequence more probable. We may now define learning as the process of coupling responses with stimuli, and ideas with ideas or perceptions. It is the establishing of definite sequences in the passage of stimuli into responses, or in the passage of perceptions or ideas to other ideas.

An Objective Consideration.—A strictly objective consideration reduces both forms of learning to one. If we study another person to ascertain the results of learning, we find only definite forms of behavior following upon definite situations. For example: if we ask a child to take pencil and paper and write the word *America,* he takes his pencil and makes the proper letters in the proper sequence. If we ask him to tell us the name of the largest city in the United States, he says the proper word. In answer to our questions, we get from the child always some form of action, as movement of the hand in writing, or of the tongue and mouth in speaking, or merely a nod or shake of the head in assent or dissent. Briefly, we learn in an obective study only about *behavior*. If we study ourselves, however, we can see a difference in the results of learning. We may sit perfectly still in our chair and have the idea *Napoleon* followed by the idea *General of the French Revolution.* There need be no movement of any muscle of the body involved in the sequence. It may be that the idea *General of the French Revolution* is followed sooner or later by muscular movements, but such movements, even granting that they take place, have nothing to do with the above mentioned sequence. The only important thing to me who has

these ideas is, *that they are coupled together*. The movements that may follow are not necessary to the sequence itself. The essential thing in knowledge is *idea*. The essential thing in habit is *movement*.

It may of course be said that *I* know nothing of another's ideas except through his movements. True enough, but *he* does. It may also be said that ideas are worth nothing to the world except as they issue in movement. This is also true. But *my* ideas may be worth something to *me* and not issue in movement. They may give quite as much pleasure and satisfaction as any that issue in movement. Neither the fact that the objective value of ideas depends upon their issuing in movement, nor the fact that we can not know another's ideas except through this other person's movements has anything to do with the existence of the ideas themselves and the connections or sequences that are organised among them. Each of us knows for himself that he has habits and organised ideas or knowledge. This distinction between the two aspects of the results of learning—objective and subjective—is clear, and it is a helpful one to make in our study of the psychology of learning.

Physiological Considerations.—It is evident that all learning is connecting stimulus with response, idea with idea. We have now to enquire concerning the nature of this connection. We have spoken of it above as a *sequence*, but have not explained the *cause* of the sequence. The sequence itself is evident, in the case of habit to objective observation; in the case of knowledge to internal observation. But why the sequence? What underlies it? Of course it may be said, and

truly, that the sequence is determined by repetition of experience. This is the cause of the sequence as one sees it on the outside by objective observation of behavior. *But what has happened on the inside, in our bodies, to determine the sequence?* Now a stimulus, in the simplest cases, is due to the excitation of some sense organ, and a response is a *muscular* contraction. The excitation passes over a neurone or series of neurones to a muscle or group of muscles and brings about a contraction. The process of learning, in habit formation, consists in doing something that insures, with more or less certainty, that the stimulus shall go to a certain muscle rather than to some other. This *doing something* consists in reducing the resistance along the nervous route that leads to the proper muscle or group of muscles. Stimulation or excitation passing through the nervous system is guided and directed by nothing other than the various resistances offered by the parts of this system. And learning consists, physiologically, *in building up and establishing preferential routes in the nervous system.* A preferential route depends upon the fact that this route offers less resistance to the particular form of excitation than do other routes. This smaller resistance is due in most part to previous passages of the same kind of excitation along the same route.

It must be pointed out that preferential routes are not fixed and static things, nor absolute and permanently definite. We can never be quite certain as to what route any stimulus will take. It is always merely a matter of probability, for the reason that nervous resistance is subject to great variation, is influenced by many factors, such as fatigue, temporary blood sup-

ply in the parts involved, immediately preceding stimulation, other concurrent stimulation, the feeling accompaniments, etc. In the light of these facts, we should say that learning, in habit-formation, consists in increasing the probability, other factors being equal, that a given stimulus will take a certain course. Learning can probably *never* insure that a given stimulus will, in spite of all other factors, go over into a certain response. As well as we know our own name, there come times when we can not immediately say it upon being asked. As well as we know to say "eighty one" for the stimulus *nine times nine,* there come times when we can not immediately do it.

The physiological basis of knowledge is precisely the same as that of habit. Knowledge is a matter of one idea following another idea. Now the reason that a certain idea, as x, follows idea a, is that the cerebral excitation underlying the idea a passes over and causes the excitation underlying the idea x. That the excitation takes this course rather than some other, and brings about the idea x rather than some other idea, as y or z, is due, as in habit, to preferential routes in the central nervous system. From the point of view of the nervous system, there is no difference whatever between habit and knowledge. From this point of view, all learning is the establishing of differential resistances in the central nervous system. The paths of smaller resistance have been called "bonds," because, in a sense, they bind together stimulus and response, or idea with idea.

Securing the Initial Connection.—Learning is connecting, but we must now ask how the connection is first secured. In the case of habit, how does the person

who is forming the habit get the stimulus to pass over to the desired response in the first place? Suppose we wish to couple the stimulus "five times five" with the response "25," we have only to tell the child to say that five times five equals twenty-five, and he says it. He is able to say *twenty-five* when he wishes, and he can couple it to any stimulus of his own volition. He has long since mastered this response. But suppose it is a very young child and we ask him to make the letter *a*. We can show him the letter and tell him to make one like it. The perception of the letter may be considered the stimulus. But the child can not immediately make the letter. This is a response which he has not yet mastered. How does he master it? With pencil in hand he continues to make marks on the paper. The results of the first trials may have no resemblance to the letter *a*. The stimulus being maintained, the efforts continue. Each time the response is somewhat different. Slowly the marks begin to resemble the copy. This form of learning has been named the *trial and error method*. It is the only method in habit-forming *when the movement involved has not already been mastered and coupled with the idea of the movement as its stimulus*.

During the early years of infancy the child, by the trial and error method, is learning to make movements with all the muscles of his body. Especially is he getting control of legs and arms and hands and feet and of the vocal organs. In these early years he learns to make nearly all possible movements with his hands and vocal organs, and these movements are organised with the cortical substrate of their corresponding ideas as their adequate stimuli. This learning is so far

advanced when the child enters school, that he can make with some degree of precision, any kind of mark he is shown or told to make. He can also make any sounds he hears or is told to make. These last two statements are not wholly true, for there will be some movements and sounds not wholly mastered. But most of the movements and vocal responses have been mastered, so that little trial and error learning is left to be done. Many of the child's responses will be crude and will have to be perfected through practice. The method of perfecting them is the trial and error method. The fact is, that when a child enters school much learning has already taken place. He has partially mastered most of the responses that will ever be required of him. What remains is to couple these responses to their appropriate stimuli, and this is done by what may be called the *ideational method.* This method is possible only after the movement involved has been attained by the trial and error method and connected with its idea as its adequate stimulus. As previously explained, when we speak of an idea as a stimulus, we mean the cortical activity which is the neural correlate of the idea.

In the case of knowledge, the initial connection between the ideas is secured by simultaneous experience. If we wish two ideas to be joined together in our minds, so that when one of the two ideas comes, the other follows, we must experience these two ideas together. And the oftener the ideas are experienced together, the more surely will one arouse the other. Suppose I wish to teach a child the names of the parts of a flower and the functions of the essential parts of the flower. I show him a flower and tell him its name. The idea of the

thing becomes associated with the name through simultaneous experience. I then point out the different floral organs, the calyx, corolla, stamens and pistil. As the child looks at each organ, I pronounce the name of the organ upon which his attention is fixed. In this manner the things and their names become coupled together. Then in a similar manner we couple the names of the parts with the functions of the parts. In knowledge-getting in all its various fields, our only method of connecting ideas together is by experiencing those ideas together in a state of attention. Since an idea can enter into any number of such connections, all of our knowledge becomes connected or related, so that we are able to go from any idea to any other idea through intermediary ideas. For example, horse is connected with buggy through simultaneous experience, similarly buggy with city, city with Athens, Athens with Homer, Homer with the *Iliad*, *Iliad* with school, school with a certain classmate, this classmate with death, death with heaven. Similarly all the items of our experience are united so that we can go either directly or indirectly from any bit of experience to any other, although the only method of uniting these bits of experience is through simultaneous experience.

The above account of the method by which stimuli are first connected with their responses and ideas with other ideas is objective and to some extent superficial. We have described merely what is seen on the outside. What goes on inside is not entirely clear. Why two cortical processes which underlie two ideas simultaneously experienced should be so related that when later one of these processes is revived it should revive the other, is not known. Probably two simultaneous brain

processes are to some extent one process, and flow into one another, so that they become more or less a unity. If such is the case, then later when one of the processes is revived it revives the other because it is really a part of the other, or rather they both constitute but one process.

In the case of habit, it may well be asked why, when a child tries for the first time to make the letter *a*, whatever the first response, does he not continue to make the same marks over and over again instead of making somewhat different marks at each trial? It is possible that the stimulus changes somewhat with each trial. The child sees that the first result is not the result desired, this very fact makes the stimulus for the second attempt a somewhat different stimulus. Moreover, the resistances along the various possible routes are doubtless not very different so that the slightest change in resistance makes the stimulus take a somewhat different route producing a different result. Probably the fatigue toxins are sufficient to change the resistance temporarily. Possibly also the physiological correlates of the feeling element involved have their effects in varying the resistances and shifting the direction of the excitation. These suggestions are entirely theoretical, and we must confess that we are ignorant of the nature of the neurological processes which constitute the causes which we are seeking. For the present we must be content with the objective statement of facts given above. Fortunately this objective statement is sufficient for our practical purposes.

Function of Habits.—Habit is the basis of efficiency. It insures, as much as anything can insure, that the right response follows upon the appropriate stimulus.

Habit enables us to perform an act with greater accuracy, greater speed, less waste of energy, and consequently with less fatigue. Motor efficiency is impossible except through habit. In whatever field our work may be, whether in carpentry, masonry, farming, blacksmithing, engineering, or cooking, we become efficient only through habituating the processes. There is no other way. It is true that habituation resists change. Through habit we become set and fixed, but this is the price that we must pay for efficiency.

If we consider the function of habit from the mental side, the subjective side, we find that habit removes actions to the control of lower cortical levels, relieving the higher levels which are thereby freed for other processes which may go on simultaneously. In other words, habit removes an act from the state of focal attention, leaving the higher attention levels for other processes. For example, when we are learning to run a typewriter, the operation of the machine demands all of our attention. After we have become expert in running the machine, the mere mechanical work demands little or no attention.

Function of Knowledge. — The chief function of knowledge is to put meaning into the world. The getting of knowledge consists in learning the names of things and the functions of things. It is only the fact that we live a social life and need to communicate with one another that makes it necessary to learn the names of things. If we lived an individual, solitary life, we should not need to know the names of things, therefore the essential thing in knowledge is the coupling of the thing with its functions. Now all things in the world are related, and through experience we learn the func-

tions of things, or in other words, their characteristics, what they do, what we can do with them. The world has unity and order in it. Through our experience, we get this unity, this order; we learn the several uses to which the various things in our environment can be put. For example, we have experience with a substance which we name *iron.* We learn that it is hard, tough, heavy, that it gets red when heated, white and malleable when heated still more. We learn that we can hammer it till it has a sharp edge and then we can cut with it; that we can mould it into various shapes and make it into a multitude of useful instruments and implements. In a similar way we learn of all the substances and organisms of our environment. We come to know the world as it is. This knowledge of the world gives us control of the world. The function of knowledge is, then, to put meaning into the world, and through this meaning to give us control of the world. We build an inner, thought world, which corresponds to the outer world. The closeness of the correspondence between our inner world and the outer world indicates our approach to the truth. If the correspondence is not fairly complete and accurate, we are in error, we can not use the outer world. We can not use it because we do not really know it. We do not have its true meaning.

Plasticity.—By plasticity as uesed here, we mean the ease with which we can be changed, more particularly the ease with which new bonds can be established in our central nervous system. As we grow old we lose plasticity chiefly for the reason that in our earlier years definite responses are established for most of the situations of life. The passage of the same excitation over the same set of neurones, time after time, produc-

ing the same action sets up a path which resists change. By the time we have reached middle life, most of the situations of life have occurred repeatedly; forms of response more or less definite have been established for all of them. Therefore, in familiar situations we become more set with each succeeding year. However, we do not lose plasticity in unfamiliar situations, as far as is known, until the decadence of the latter part of life sets in. But after we reach middle life there are not many unfamiliar fields. There are then very few situations which we do not approach with some bias or prejudice. Apart from the resistance of bonds already formed our ability to form new bonds increases up to maturity, and probably does not decrease till after middle age. This statement is based on a comparison of the learning capacity of men and women in their forties with that of children of high school age and younger. In fields wherein men and women are not incapacitated and hindered by virtue of prejudicial bonds already formed they learn as readily as do boys and girls, much more readily than young girls and boys.

Man as the Result of His Learning.—Let us now consider the importance to our lives of habits and knowledge. Thorndike has truthfully said that the most important thing about human nature is that it can be changed. Let us couple with this statement another common saying, namely, that a man is the sum of his tendencies. A careful consideration of these two facts gives us an idea of the importance of education. What we are at maturity depends upon the habits and knowledge that we have. Acquiring these habits and getting this knowledge constitute our education. Whether we are a Methodist, Presbyterian or Catholic depends

upon our education. Whether we are a republican, democrat or socialist depends upon our education. Whatever motor performances we are capable of depends upon our education. Our ideals of life, of work, of duty depend upon our education. Briefly, all our skill, all our knowledge is merely the result of the bonds that have been formed in our central nervous systems. In a very true sense a man is *made*. He is the product of all the forces that act upon him, particularly of those that act upon him in his earlier years. We do not mean to minimise the importance of original nature. The same forces do not make the same result out of two different children. We can not make the same kind of chair out of pine that we can out of oak, nor can we make the same kind of man out of one child that we can out of another. What we are at maturity depends upon the modifications that have been wrought upon original nature. Bringing about these modifications constitutes our education, and education is important to the extent that these modifications are important. And they are of tremendous importance in the life of every individual. The child comes into the world with a multitude of original tendencies and capacities. Upon these the forces of the environment, of home, school, companions, and the whole animate and inanimate world work, forming and moulding and fashioning the individual into the thing that he is to be, namely a being with a background of feelings and passions and instincts, to which is added a multitude of acquired tendencies to act in definite ways to the various situations of life; a being with myriad ideas all interrelated, each idea coupled with others; a being with ideals, ambitions, desires; a being of hates and loves and jealousies,

—all the resultant of the original tendencies provided by heredity and the forces of the environment that have acted upon the individual. The changes that are wrought in us constitute the results of learning. The investigation of their nature and of how they come about is the purpose of this book.

CHAPTER II.

THE LEARNING CURVE.

Progress in learning is ordinarily shown by a curve. We must now see how such curves are constructed, how they should be interpreted, notice the various types of curve, and the laws of learning which they exhibit. We must study also the various factors which enter into them, and which determine their upper limit.

The Construction of a Learning Curve.—The purpose of a learning curve is to show the increase in efficiency due to practice. It is customary to indicate the successive practices on the horizontal axis, as BC in Fig. 1. The scale for the scores is indicated on the vertical axis, AB. The scores are shown by the dots above the numbers on BC which represent the successive practices. The line DE joining these dots is the learning curve. Its rise indicates the increasing efficiency due to practice.

Another method of constructing the curve is shown in Fig. 2. The curve is constructed as follows: Instead of representing successive practices by points on the base, we represent them by successive distances. The scores are represented by horizontal lines, drawn at the proper height and of the same length as the distances on the base which indicate the practices. Either of these forms of curve shows the facts as well as the other, but if curves are to be drawn with the same axes for purposes of comparison, the form of curve shown in Fig. 1 is more convenient.

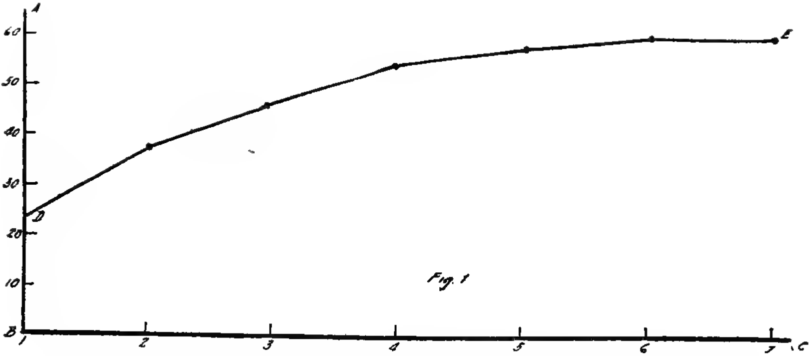

FIGURE 1. LEARNING CURVE. Card-sorting, fifteen boxes, five cards to the box, experiment continued five days, four sortings first day, eight sortings on each succeeding day, 12 subjects. Every sixth record is taken for the construction of the curve. The records are in terms of cards sorted per minute.

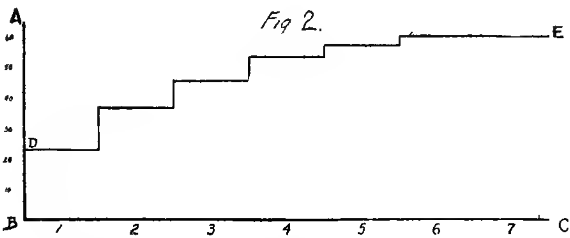

FIGURE 2. LEARNING CURVE. Data same as for Figure 1.

In figures 1 and 2, increasing efficiency is shown by a rise in the curves. The curves indicate the amounts of work done in successive equal periods of time. Another method of constructing the curve is to show the amount of time required to do successive equal amounts of work. By this method, increasing efficiency is shown by a fall in the curve. It may be illustrated by the same card-sorting data used in constructing the graphs in figures 1 and 2. In the card-sorting experiment from which this data was obtained, seventy-five cards were sorted into fifteen pigeon holes or card trays. Each tray was numbered, and the cards were numbered correspondingly, five to each tray. At each practice, all the seventy-five cards were distributed. With each practice the time required for sorting the cards became less and less. This is shown in Fig. 3. To convert the data into the form used in figures 1 and 2, the number of cards sorted per minute in each practice was com-

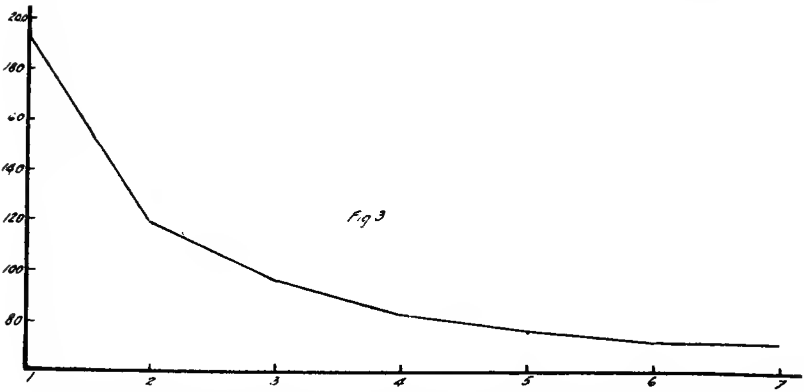

FIGURE 3. Data from same experiment as in figures 1 and 2. Records in terms of number of seconds required to sort the 75 cards. Increased efficiency is shown by the fall in the curve.

puted. Therefore figures 1 and 2 show the increasing number of cards sorted per minute in the successive practices, while figure 3 shows the decreasing amount of time required to sort the seventy-five cards in the successive practices. In the discussion of learning curves which follows, we shall have in mind the types of curve shown in figures 1 and 2, in which efficiency is shown by a rise in the curve.

The Rise of the Curve.—Why does the curve rise? To what is the increased efficiency due? Increase in efficiency from practice is due in general to three causes: (1) The establishing of the bond between stimulus and response. This bond, in physiological terms, is the shortest possible route between stimulus and response. (2) The second factor is decreased resistance in the established neural bond or route. (3) The third factor is the adaptation of the muscles to the special movements required. In the present discussion, we are considering learning of the habit-forming type, and not ideational learning in which the motor element is unimportant.

We shall now illustrate the various learning factors from the card-sorting experiment. We sit down to the experiment for the first time. We take the pack of cards in our left hand and remove a card with the right hand. Let us suppose the card is number seventeen. We look over the box numbers until we find number seventeen, and then deposit the card into this box. We take another card. Suppose it is number 20. We must search for box number 20, and so proceed until all the seventy-five cards are distributed. When we have finished, we have put five cards into each box. The first card sorted was number 17. After a few seconds we

came to another card numbered 17. We may have remembered the location of this box, more likely we did not. But before the first experiment was over we did learn the location of some of the boxes and did not have to search for them. With each successive sorting, we remembered more and more of the boxes, until finally we knew the location of all of them and did not have to search for any of them. However, it must be pointed out that all learning is a matter of *degree.* I have said that we come to know where all the boxes are. We do, but at first *we know it poorly.* The associations come slowly. While we do not have to hunt for the boxes, the kinaesthetic or visual idea of their location comes to us slowly, and the movements therefore follow slowly. With more practice, the movements follow their stimuli more quickly, more definitely, more surely. The associative processes run their course faster and faster.

In the early stages of practice, after we have learned the location of all the boxes, we may at any time be temporarily unable to recall the location of a box which we remembered on a former trial. This is because the bonds are only poorly established, and at any moment may break down and fail us. With increasing practice, this failure of a particular association to run its proper course happens less and less, and the certainty that all the associations will take place quickly becomes greater and greater. But, as pointed out in Chapter I, this certainly is never absolute.

In the early practices, while the neuro-muscular coordinations are weakly established, the hand often starts the wrong way, but before it reaches the box, we recall the right place and have to make a second movement. With increasing practice, these false move-

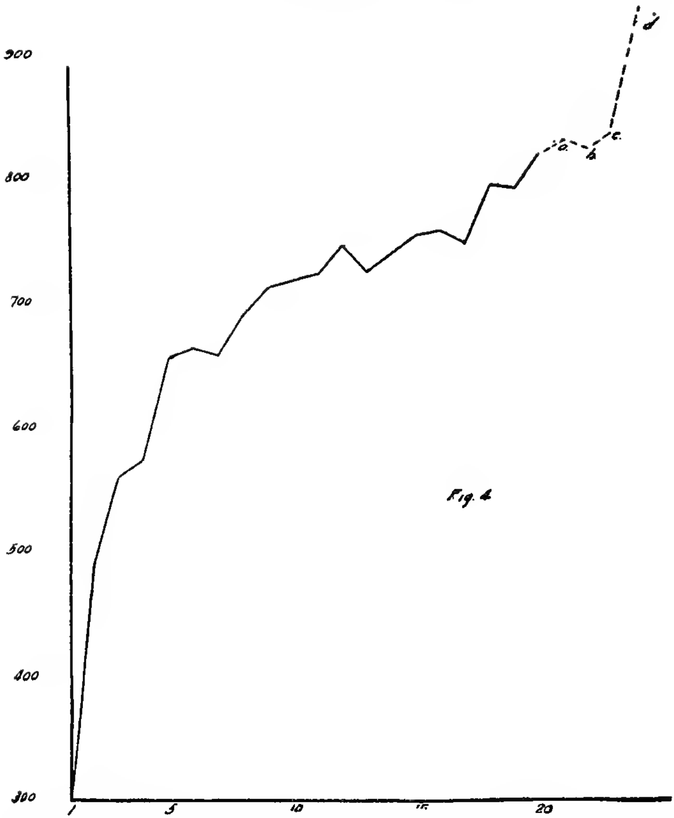

FIGURE 4. LEARNING CURVE showing the effects of long continued practice. Card-sorting, 30 boxes, five cards to the box. The records from which the curve is made are the reciprocals of the scores in seconds. These reciprocals are made proportional to the number of cards per second. The practice was first for 20 successive days, five practices the first day; seven, the second; eight, the third and fourth; nine, on the fifth, sixth, seventh, and eighth; and ten on all succeeding days. Fourteen days later, the practice was resumed for two days, and seven days latter, for four days. The records attended on these latter practices and indicated by the letters a, b, and c. Practice was continued at intervals for four months longer, a record of 935 being reached, indicated by d on the curve.

ments become fewer and fewer. With every day of practice, it becomes more and more certain that when we take a card from the pack, the hand will go unerringly and with no loss of time or waste of motion, to the appropriate box.

It is surprising to one unacquainted with work in the psychology of learning to discover how much improvement is possible after one has learned the location of all the boxes. In a few days one knows the boxes so that he does not have to hunt for them, but improvement will continue for months. This fact is illustrated in Fig. 4. Under the author's direction, Miss Rose Ann Howe sorted cards for several months. In her experiment, she sorted 150 cards into thirty boxes, five cards to the box. After a few days she knew the location of all the boxes, nevertheless improvement continued for several months. This fact is even better illustrated by the substitution experiment, performed by the same subject. In this substitution experiment, letters were substituted for the nine digits. There were but nine bonds to form. After two or three five-minute practices, these nine bonds are established. However, improvement continues for twenty days, as shown in Fig. 5. The experiment consisted in transcribing columns of numbers into letters according to a key furnished the subject. Practice was continued for twenty-five minutes at a sitting each day. The key was learned during the first day's practice. On the second day the average score was 280 substitutions in five minutes. On the twentieth day the score was 720 substitutions in five minutes. Now since the key was known on the second day, why the greater score on the twentieth day? The answer again is that learning is a matter of degree.

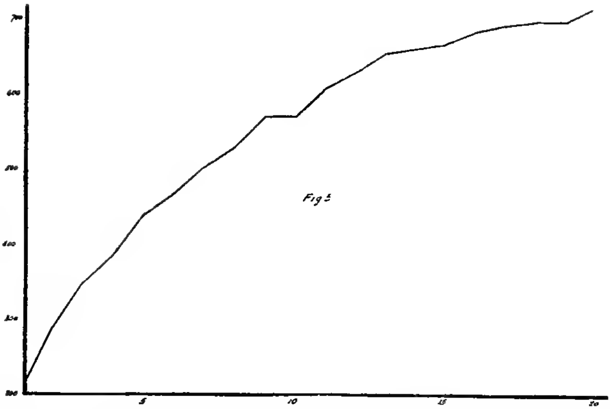

FIGURE 5. DIGIT-SYMBOL SUBSTITUTION, 20 days of practice, five practices a day, five minutes at a practice. Records, average correct substitutions in five minutes for each day. The days are represented on the horizontal axis, the scores on the vertical.

While the key was known by the end of the first day's practice, it was known better on each succeeding day. The bonds became better and better established with practice; the certainty that the proper association would come instantly became ever greater and greater. Moreover, the muscles became adapted to their work. With practice, there was less waste of energy through false and awkward movements; the muscles gained strength and facility in co-ordination.

Again we have the same three factors of explanation: forming the primary bonds, strengthening these bonds through use, and adapting the muscles to their work. In both the card-sorting and the substitution experiments, the neuro-muscular systems involved become organised so that the stimuli run their courses with the least possible obstruction and expenditure of energy. To summarise: Improvement shown by the rise

of the curve comes from establishing the proper bonds, eliminating the wrong or useless bonds, strengthening the established bonds through use, and the adapting of the muscles involved to the movements required in the habit.

We shall now give a further illustration of the whole procedure by the process of learning to add. Let us take a problem of four numbers, three digits each:

987
789
654
456

suppose we know merely how to count. We take six, count four more and have ten. We then count nine more and have nineteen, then seven more and have twenty-six. With practice we come to know that six and four are ten and then do not have to count, we look at six and four, and say "six and four are ten," then having learned the other combinations, say "ten and nine are nineteen, nineteen and seven are twenty-six." Later we shorten the process and say merely "ten, nineteen, twenty-six." Later still, the six and four become a unity and mean ten as definitely and directly as one figure by itself means "six" and the other "four." So the nine and seven come to mean "sixteen," then the addition becomes "ten and sixteen are twenty-six."

In the early stages, we get the sums of the second and third columns by the slow process of counting, and the process of carrying from the first to the second and from the second to the third must be learned. With practice, however, we can add two columns at once as fast as formerly we could add one column. We can also learn to add three columns at once with great speed and accuracy.

In adding we first learn all the possible combinations of the nine digits. These are the primary bonds, the basis of all later schemes of adding. Through practice we come to eliminate all useless bonds, as in saying "six plus four are ten." We simply look at the six and four and say "ten." With the ten in mind, we look at the nine and say "nineteen." With the nineteen in mind, we look at the seven and say "twenty-six."

After we have learned all the primary combinations, practically unlimited improvement is still possible, through strengthening the primary bonds, and com-

FIGURE 6. PRACTICE CURVE, dealing 53 playing cards into a box, 10 times a day for 15 days. The records shown on the vertical axis are the daily averages, expressed in seconds. It will be seen that the time required to deal the pack of cards was reduced to less than a third of the time required on the first day. The graphs show the records of two women, but of whom were used to dealing cards The amount of improvement shown, for so simple a function, is very great.

bining into unitary processes what are at first complex processes. As shown above, after we have practiced a while, 6+4 are not two things but one thing and mean "ten," directly and immediately. With further practice, larger and larger groups of digits coalesce, become a unitary process, and *mean their sum.*

All habit-formation of the motor type is essentially the same. In general, the same factors are involved. The illustrations given above are typical of the processes in all complex habits.

The Limit of Improvement.—In a simple habit the limit is soon reached. What this limit is, is determined by the subject's reaction time. Suppose that, instead of sorting cards, we take a pack and put all of them into the same box as quickly as possible. The neural bond is soon established and we reach a limit determined by the time required for the nervous impulse to travel along the necessary route. Such a curve is shown in Fig. 6. In general, the more bonds involved in the habit, the longer it takes to perfect them. If the bonds required are many, say those involved in sorting cards into one hundred boxes, improvement would continue for many months.

In such a process as addition, improvement is practically unlimited, for higher and higher orders or habits can be formed indefinitely. In such a case, improvement comes not merely from perfecting habits, but from developing *more and more efficient habits.* But in all cases in which the habit is definite and can not be supplanted by a more efficient habit, there is a limit which may be called the *physiological limit.* This limit varies with different individuals, and, as above stated, depends upon their reaction times. In the card-sorting

experiment, the correlation between reaction time and efficiency becomes higher and higher with succeeding practices.

Practical Limits.—As pointed out by Thorndike*, few people in the ordinary pursuits of life, come anywhere near their possible limits. In typing, stenography, accounting, telegraphy, and the various other performances of the business and industrial world, workers reach a proficiency that enables them to do their work reasonably well and hold their jobs. They are not willing to put forth the effort that would carry them to a higher plane of efficiency. Most of the workers are working on an efficiency plane much below what is possible for them. One in a hundred, perhaps, puts forth such effort and passes up to a higher plane of performance. One in a thousand, having great ability and great ambition, puts forth the effort that places him among the leaders in his trade or profession.

It is well that the young know this important fact, for not only do laborers and clerks work on a level far below their possible limit, but students, as a rule, are content to continue on a level that just barely enables them to "pass." In language they only poorly know the declentions, the paradigms, the conjugations, and the vocabularies. In mathematics, the tables, the formulas, the rules and fundamental principles are not sufficiently mastered. The case is similar in science. The student should have pointed out to him that the elements can be so mastered as to enable him to proceed to a higher level of achievement. Means of practice and drill should be devised to enable the student

---

*E. L. Thorndike, *Educational psychology, briefer course*, p. 199.

to pass to a higher level. There is no short-cut; there is no easy way; there is no substitute for drill, practice, repetition. Easy, confident, and efficient performance in any field comes only from complete habituation of the elementary processes.

Different Forms of Curve.—The form of the learning curve depends upon the nature of what is learned. Usually, the initial rise is rapid, with slower increments later. This gives a curve convex on its upper side as in Fig. 5. If learning is slow at first and faster later, the resulting learning curve is concave on its upper side as in Fig. 7. Whatever the form of the curve at first, it eventually becomes level or nearly so. As we approach

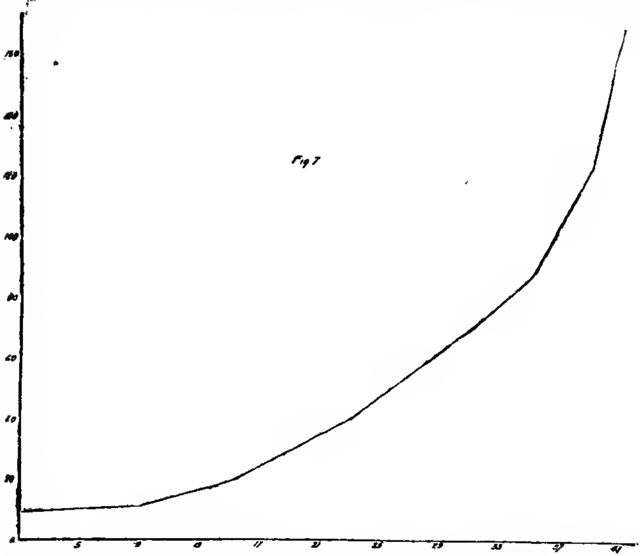

FIGURE 7. LEARNING CURVE, concave upward. Adapted from Swift. Practice was in ball-tossing. Scores shown on vertical axis represent successes. The successive days of practice are represented on the horizontal axis. A concave learning curve indicates increasing increments from the effects of practice.

our limit in any particular habit, any improvement is at the cost of much greater effort than was the case in an earlier stage of habituation.

In the psychological literature there has been much discussion of "spurts." By a spurt is meant increased efficiency as shown by an abrupt rise of the curve. With some subjects and some work there is an initial spurt. Sometimes there is a final spurt, particularly if the subject knows that the end of the work period is near. At any time during a work period a spurt may appear, due to a combination of favorable circumstances. The relative amounts of work done at different parts of a work-period depend upon several factors, particularly upon the stage of habituation and how fatiguing the work is. In the early stages of habituation, there are considerable practice effects during the work period which make the later records of the period high. If we are near the limits of practice, the practice effects during a work period will be slight. In the latter case any difference in the amounts of work done at different parts of the period will be due to the effects of fatigue and of warming up. In complicated motor performances, such as type-writing, the best record is not made at the first part of a work-period. Only after a little practice can we do our best.

In Miss Howe's card-sorting experiment, cited above, for the 18th, 19th, and 20th days, the average efficiencies for each of the ten sortings made at a sitting were: 775, 802, 804, 824, 802, 808, 796, 802, 805, 780. Maximum efficiency was not reached till the fourth sorting, when the speed was 6.3 per cent. better than it was the first sorting. The record for the first sorting was the lowest of the ten.

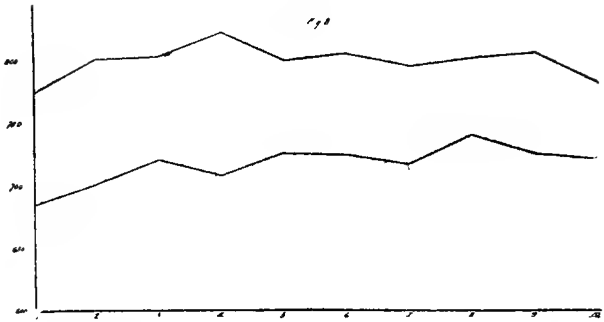

FIGURE 8. CARD-SORTING. The upper graph shows the course of efficiency during an hour's work in card sorting after the habits involved are well fixed. It shows a period of warming-up leading to maximal efficiency on the fourth practice. The lower curve indicates the course of efficiency during an hour's practicebefore the habits are well fixed. Maximal efficiency is reached on the eight sorting. In the latter case, the effects of practice raise the latter scores. The last two scores fall because fatigue offsets the practice effects. In the former case, there is little improvement due to practice in the course of an hour.

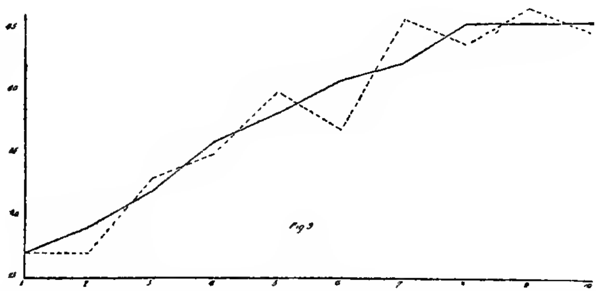

FIGURE 9. EFFICIENCY CURVE FOR CARD-SORTING. Solid line from the actual data of one subject; broken line, a smoothed curve constructed from the same data, by averaging each record with the adjacent records. The first and last record were doubled, added to the one adjacent record, and the sum divided by three. The number of cards sorted per minute is indicated on the vertical axis.

On the 9th, 10th and 11th days, while improvement was still marked, the records for the ten practices at a sitting were 685, 702, 721, 709, 728, 725, 718, 741, 725, 720. The highest record was made on the 8th sorting, when the speed was about 8 per cent. higher than on the first. These facts are shown graphically in figure 8.

Smoothing the Learning Curve.—Ordinarily there are fluctuations in the rise of a learning curve. It rises fast, then perhaps more slowly; it may even fall, for just as a combination of favorable factors makes it rise, so a combination of unfavorable circumstances may make it fall. There are always many independently variable factors that combine to produce a learning record. These factors are variously combined at different moments of our procedure and produce a curve of fluctuating rises and falls. The general tendency of the curve is better shown if, instead of showing the actual records, we construct a smoothed curve. There are various ways of doing this. We can do it roughly by indicating the actual records on our coordinate paper by dots and then drawing a curve that throws as many of the dots on one side as on the other. The dots show the actual records, the curve shows the general tendency of the records. Another method is to eliminate the temporary fluctuations of the curve by averaging each record with the adjacent records above and below. The first and final records are doubled and combined with the one adjacent record, and the sum divided by three.

Learning Plateaus.—A plateau or level place in the learning curve indicates a period of no progress in learning. Such plateaus nearly always appear in the

actual work of learning, in school work as well as in laboratory experiments. Various explanations for the appearance of the plateau have been given. Bryan, in his early work on learning, suggested that plateaus were due to the fixing of lower order habits. Progress due to higher order habits could not come till the lower order habits were fixed. But this can not be the explanation, for fixing of the lower order habits would itself give more efficiency, and should give a continuous rise of the curve. Book's suggestion that the plateau is due to a flagging of interest, a letting up of effort, is doubtless nearer the truth for the plateau may appear in simple experiments involving a single definite habit. The fact seems to be that the plateau is not a necessity in learning, theoretically, although in practice it usually appears. As long as a learner maintains a high degree of attention and puts forth maximum effort, he continues to improve till he reaches his limit. But maintaining a high state of attention and putting forth maximum effort are impossible over long periods of time. The ordinary learner usually does his best for a time, then because of fatigue, or lack of attention, or loss of interest, he relaxes and works at a lower point of efficiency. For a time, the records may actually fall below previous records. This phenomenon may appear during the experiment of a single sitting and be a matter of minutes. It may appear in a long series of experiments and be a matter of days.

The plateau has much significance to education. When it is due to loss of interest and lack of attention, practice is not then profitable. At such a time, practice should stop or means be found to renew attention and effort. Children lose interest very quickly, and soon

cease to put forth effort in continued work of the same kind. Pauses in habit-formation are valuable not only because they lead to a renewed interest and effort when the work is taken up again, but according to some writers, they lead to a weakening of inhibitions which had interfered with the habit. Moreover, in habit-formation, time is an element which can not be ignored. Some sort of fixation goes on in the nervous system; this fixation requires time and can not be unduly hurried. As shown in a later chapter, practice beyond a certain amount at one sitting is valueless. And in practice extending over many days, only a certain amount of improvement is possible, no matter how hard we work.

EXPERIMENTS AND EXERCISES.

All the principles discussed in this chapter should, as far as possible, be illustrated by experiments. Any learning experiment will suffice, but for economy of time, an experiment should be selected that will show rapid improvement. Several experiments are described below. The instructor can select those suited to his needs, or devise others.

1. Class experiment. Material, Pyle's Digit-symbol substitution test blanks. Method: Distribute about sixteen test sheets to each student, placing them face down before the student. Explain to the students that they are to substitute letters for the nine digits, in accordance with the key shown at the top of the test sheet, and that they are to work as fast as possible. Work in five-minute periods, and let the score be the number of substitutions correctly made in five minutes. Eight such scores can probably be made in a one-hour period. The scoring should be left till the experiment is finished.

2. From the data obtained in experiment 1, construct individual learning curves similar to figures 1 and 2.

3. Construct a smoothed curve as described in the chapter.

4. Construct a learning curve from the class averages for each five-minute period. Note that it is smoother than the individual learning curves. Why?

5. Laboratory experiment. Card-sorting. Material, ordinary playing cards. Method: Shuffle the cards, then sort them into four piles according to suit, *i. e.*, hearts together, spades together, clubs together, and diamonds together. Determine the time for each sorting. Construct a curve similar to figure 3.

6. Laboratory experiment. Material, card-sorting box and cards. Method: Use only one row of boxes, five cards to each box, and determine the time required for each sorting. The cards must be thoroughly shuffled before each sorting. Shuffling is facilitated if the cards are taken up after sorting, promiscuously, one at a time. Ten sortings can be finished in an hour. Construct individual learning curves similar to figure 3. By computing the number of cards sorted in a minute, curves can be made similar to figures 1 and 2.

7. Laboratory experiment. Material, mirror-writing apparatus. Method: The hand of the writer is to be covered from view. He is to see his hand as reflected in the mirror, which is vertical before him. The subject is to write in script in such a way that the letters appear in the mirror as they would on a sheet of paper held vertically before him. Let the subjects copy the material of the first paragraph in this chapter. Record the number of letters written legibly in each successive minute. Construct individual learning curves similar to figure 1. How do the curves differ from figure 1?

REFERENCES.

Batson, W. H., *Acquistion of skill*, P. Mon, No. 91, 1916.

Book, W. F., *The psychology of skill with special reference to its acquisition in typewriting*, 1908.

Bryan, W. L., and Harter, N., *Studies in the Telegraphic language; the acquisition of a hierarchy of habits*, P. R., vi, 1899, 345.

Chapman, J. C., and Nolan, W. J., *Initial spurt in a simple mental function*, A. J. P., xxvii, 1916, 256.

Chapman, J. C., and Hills, M. E., *Positive acceleration in improvement in a complex function*, J. Exp. Psych., i, 1916, 494.

Peterson, J., *Experiments in ball-tossing; the Significance of Learning Curves*, J. Exp. Psych., ii, 1917, 178.

Phillips, F. M., *Comparison of the work done in the successive minutes of a ten-minute practice period in the fundamentals of arithmetic*, J. E. P., vii, 1916, 271.

Swift, E. J., *Studies in the psychology and physiology of learning*, A. J. P., xiv, 1903, 201.

Thorndike, E. L., *Educational psychology*. Briefer Course, 1914, Chapters xiv and xvi, a Systematic Treatment.

CHAPTER III.

ECONOMICAL LEARNING.

ENGTH AND DISTRIBUTION OF PRACTICE PERIODS.

Learning is connecting. After the initial connection secured, we must strengthen and perpetuate it rough repetition or practice. The first important oblem in the economy of learning is concerning the oper length and distribution of practice periods. By *roper* length and distribution, we mean that length ıd distribution which gives the most return in effiency for the amount of time spent in practice. Our oblem, then, is to find what length and what distriıtion of practice periods will give the best returns. r, to state the problem in still a different way: after e have secured the passage of a stimulus over into its opropriate response, how many times should this pasıge be repeated before we rest? And how long an terval should elapse before the processes are reeated? We turn to the experimental evidence.

Experiments with Nonsense Syllables.—The early exeriments of Ebbinghaus and Jost showed the advange of short periods of practice distributed over a long me as compared to longer periods of prcatice distribed over shorter lengths of time. All the experiments ıat have since been performed in this field have in eneral confirmed the earlier work and have made it ear that for every kind of learning there is a proper

length of practice period, and for the different stages of habituation, there is also the proper distribution of practice periods.

Jost, comparing ten repetitions a day for three days with thirty repetitions in one day, found a saving of fifteen per cent., from the shorter periods. From the first it has been evident there is a certain advantage in spreading practices out, temporally, rather than in concentrating them. There is an aspect of learning that *requires time*, an aspect that resembles growth. Growth is a process that can be hastened only to a limited extent. Such seems to be the case with habit-formation. A certain amount of practice at one time is efficient in fixing a habit, more practice at the same time, without intermission, does no good, is time wasted as far as fixing the habit is concerned.

More recently Perkins has continued the study with nonsense syllables. She states her problem as follows: "My own experiments were designed to ascertain how much further in the distribution of readings one might go than Jost had gone before a limit would be reached in learning nonsense syllables. The best arrangement of readings involves two questions,—how many repetitions should be used at each period, and, for each number of repetitions per period, what interval between periods is best?" In her experiments, she used seven-paired series of nonsense syllables. They were presented visually at the rate of one in three seconds with three seconds interval between. She compared one repetition a day with two, four, and eight repetitions a day. She tested learning by a retention test given two weeks after the last presentation of a series, and stated her results in terms of the per cent. correct.

The average per cent. correct for all the series given, for one, two, four, and eight repetitions a day, were, respectively, 75.25, 57.75, 42, 13.25. It is seen that one repetition a day was most effective, two repetitions next in value, four next and eight least effective. In Perkins' experiments, each series was presented sixteen times. The learning was therefore spread out over a period varying from two to sixteen days.

It is evident from Perkins' experiments, and this point has been confirmed by extensive experiments in the author's laboratory, that when a series of nonsense syllables has been presented to a subject once, further presentations at the same sitting have less value than the first presentation. After one presentation, to get the most value from another, time must elapse.

The Substitution Experiments.—In the solution of the problem under consideration, three experimenters, Dearborn, Starch, and Pyle, used some form of substitution experiment.

In some class experiments, Dearborn found ten minutes practice a day better than five minutes twice a day. Starch compared four different methods of using 120 minutes: 10 minutes twice a day for six days, 20 minutes once a day for six days, 40 minutes every other day for six days, and 120 minutes at one sitting. Five-minute records were kept. The results are shown in Fig. 10. The ten and twenty-minute practices were best. There was little difference between ten and twenty minute practices. The average speed of the ten-minute practices was best, but the final speed of the twenty-minute practices was best. Forty-minute practices are not so good as ten and twenty, and one hundred and twenty minutes at a sitting gave the

poorest results. The experiment is inconclusive, however, because Starch did not measure the learning capacity of his different groups, and part of the difference shown by the curves of Starch's four groups is doubtless due to differences in the learning capacity of the different groups. For the first two five-minute records, the ten-minute and forty-minute groups are better, indicating better learning capacity. The twenty-minute

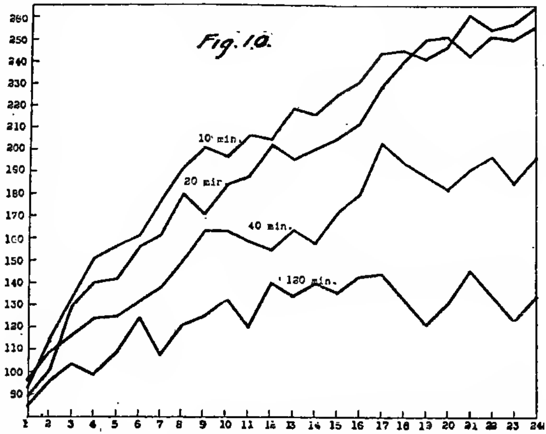

FIGURE 10, FROM STARCH, showing the effects of practice period of different lengths.

group makes a lower record, showing smaller learning capacity. In spite of this fact, the twenty-minute group makes the best record for the last five or six periods. The forty-minute group starts high. Forty minutes is evidently too long a period for best results. The fact that the 120-minute group is lower for the first two five-minute periods shows the group to be the poorest learners, but the very poor scores made in the latter half of the experiment are doubtless chiefly due to

method. The legitimate inferences from Starch's experiments are: a twenty-minute practice period is best, a ten-minute period is nearly as good, forty-minute period not so good, and a hundred-and-twenty-minute period is poorest of all. Starch did not use a thirty-minute period, which, in the author's experiments, has proven better than longer or shorter periods.

In the author's attempt to solve this problem, a group of students was required first to spend sixteen days in a check experiment, in which all used the same length of practice period and the same distribution of practices. The subjects then used different lengths of practice periods, and their learning curves were compared with those made when all used the same method of procedure. Fifteen, thirty, forty-five, and sixty minute periods were compared. The results are shown in tables 1 and 2.

TABLE 1.

DIFFERENT LENGTHS OF LEARNING PERIODS COMPARED ON THE BASIS OF AVERAGE SPEED.

Subject.	Method.	Improvement.
A	15 minutes	4.8 per cent. less than in check experiment.
B	30 minutes	30.3 per cent. better than in check experiment.
C	45 minutes	20.6 per cent. better than in check experiment.
D	60 minutes	22.9 per cent. better than in check experiment.

TABLE 2.

DIFFERENT LENGTHS OF LEARNING PERIODS COMPARED ON THE BASIS OF FINAL SPEED ATTAINED.

Subject.	Method.	Improvement.
A	15 minutes	12.7 per cent. less than in check experiment.
B	30 minutes	6.1 per cent. less than in check experiment.
C	45 minutes	3.3 per cent. more than in check experiment.
D	60 minutes	5.7 per cent. less than in check experiment.

TABLE 3.

COMPARISON OF DIFFERENT LENGTHS OF PERIODS ON THE BASIS OF AVERAGE SPEED, SAME AMOUNT OF TIME.

Subject.	Method.	Improvement.
A	15 minutes	22.3 per cent. better than in check experiment.
B	30 minutes	36.1 per cent. better than in check experiment.
C	45 minutes	25 per cent. better than in check experiment.
D	30 minutes	14.8 per cent. better than in check experiment.

TABLE 4.

COMPARISON ON BASIS OF FINAL SPEED, SAME AMOUNT OF TIME.

Subject.	Method.	Improvement.
A	15 minutes	4.9 per cent. less than in check experiment.
B	30 minutes	18.1 per cent. more than in check experiment.
C	45 minutes	5.4 per cent. less than in check experiment.
D	60 minutes	45.5 per cent. less than in check experiment.

In table 1 the comparison is made on the basis of the average speed of the whole experiment. In table 2 the comparison is based on the final speed attained. By the latter method of comparison, the forty-five-minute practice proves a little better than the thirty-minute practice, and an hour gives almost the same return as a half hour. In both tables 1 and 2, the subjects are compared on the basis of the same number of practices, but the extreme difference in the total amount of time put in is as one to four. It is clear that very little return comes after the first thirty minutes of practice. The fatigue of the latter part of an hour's practice makes the record show up poorer than that of a forty-five minute period, and but a trifle better than that of thirty minutes.

In tables 3 and 4 we compare the four different methods on the basis of the same actual amount of time, and of course, different numbers of practice periods. A

study of these tables shows that thirty minutes is the best length of practice period. The second fifteen minutes of practice continues to give a good return, but the third fifteen minutes shows a decreasing return. Fifteen minutes is too short a period in the kind of work done in the experiment to give the best return, and forty-five minutes makes too long a period. The hour period shows up poorly partly because the fatigue of the latter part of the hour cuts down the score and obscures the effect of the work in the early part of the hour. Of course it is possible that the poor work during the latter part of the hour actually decreases the effect of the work of the first part of the hour.

Experiments in Archery.—Murphy's experiments in javelin throwing were chiefly concerned with the interval between practices. He did, however, compare ten throws once a day with five throws twice a day and found ten throws once a day better. Murphy does not compare ten throws at one practice with more than ten throws at one practice, or fewer than ten throws.

Experiments in Adding.—Kirby, Hahn, and Thorndike have compared various lengths of periods in learning to add. Kirby and Hahn worked with children, Thorndike with university students. Kirby and Hahn compared very short working periods.

Kirby gave a fifteen-minute initial and a fifteen-minute final test and forty-five minutes intervening practice. These forty-five minutes were divided up into practices of 22½, 15, 6, and 2 minutes. The median gain per cent. for these groups in order were 45, 43, 42, and 56. As between the three longer groups there is very little difference, with the advantage in favor of the longer period. The two-minute period gives a

better return than either of the longer periods. The practice with the $22\frac{1}{2}$-minute group covered a period of only two days, while practice with the two-minute group covered a period ten times as long, and in the latter case, the regular school work and the work outside of school could have a much greater effect on the score than in the longer periods.

Hahn does not find greater value in the short periods. Nor does Thorndike. His experiments consisted in practical adding by means of a table. There were 80 operations on a sheet. Eight sheets at a sitting proved more valuable than two sheets at a sitting. He reports that he finds "little or no advantage in very short periods of learning."

Distribution of Practice.—After we have practiced at one time as long as practice is profitable, how soon can we practice again with profit? In general, the experiments have shown that the best prcatice interval is one day, but twice-a-day practice and alternate-day practice is nearly as profitable as daily practice. However, much depends upon the nature of the learning and the stage of habituation. We shall very briefly give the results of the most important experiments.

Murphy compared the results of throwing ten javelins at a time daily with throwing five at a time twice daily, and found the once daily method best. As for the other forms of distributing the practices he reports that "learning periods can be distributed by giving alternate days practice, and even weekly practice without any loss in learning."

In a typewriting experiment covering a period of ninety half-hour practices, the author compared two half-hours a day with ten-half-hours a day. In the

former case, the half-hours were one in the forenoon and the other in the afternoon. In the latter case, the ten practices had half-hour intervals of rest between. The results of the experiment may be brieflly stated as follows: Concentrated effort is efficient for about five practices, but the speed improved very little on the first day after the fifth practice. The effect of the early practices is evidently much greater if soon repeated. From the fifth practice to the fortieth, the group practicing twice a day steadily gained on the other group. From the fortieth to the sixtieth practice, the difference between the groups diminished. To summarise: in such work as typewriting, distributed practice is best, but concentrated practice brings in good returns, and if one is in a hurry to acquire skill, the diminished returns from concentrated practice need not be considered prohibitive. In the above comparisons we have had in mind the same number of hours of practice. The relative value of one-hour-a-day practice as compared to five hours a day, is shown graphically in figure 11. If we consider merely the number of days spent in practice and disregard the total number of hours actually spent in practice, we can say that ten half-hours a day is better than two half-hours a day. The group practicing ten times a day has a much faster speed at the end of nine days than does the group practicing only twice a day. But if we consider the amount of time actually spent in practice, we get more return for each hour of practice if the practices are spread out over 45 days. The middle line in the figure represents the results of ten half-hour practices a day for nine days. The lower curve shows the results of nine days

of practice, two practices a day. The upper curve shows the results of the same amount of practice as shown by the middle curve, but spread out over 45 days instead of nine days. Five hours a day with intervals between the practice periods are more effective in fixing the typewriting habits than one hour a day. Just where decreasing returns begin, in repeating practices on the same day, can not be determined from the experiments. In the early part of the experiment it is at the end of the fifth practice. Later in the experiment it is probably earlier, perhaps at the end of two or three practices.

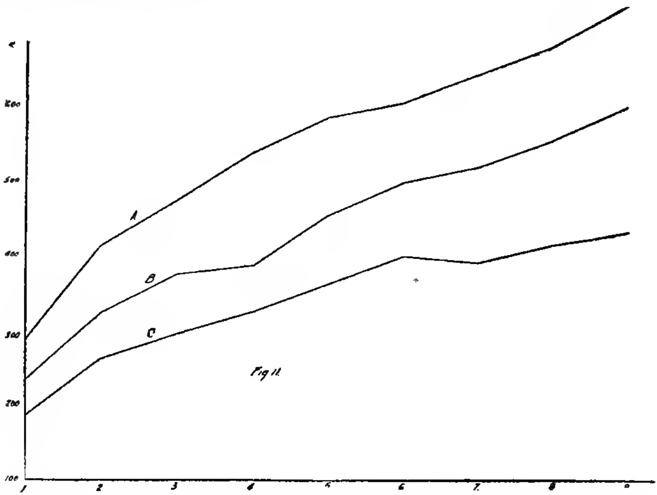

FIGURE 11. B shows the effects of practicing ten half-hours a day for nine days. C shows the effects of practicing two half-hours a day for nine days. A shows the effects of the same amount of practice as B, but at the rate of two half-hours a day for 45 days. In A and B the graphs are constructed from the averages of successive practices in groups of 10. In B the 10 practices were done in one day; in A, they were done in five days.

In the author's substitution experiments, three different forms of distribution were compared, twice-a-day, daily, and alternate days. If our basis of comparison is the total number of hours of practice, the most economical procedure is found to be daily practice. A second practice on the afternoon of the same day gives nearly as much return as the morning practice, and in the later stages of habituation, alternate days practice is probably as effective as daily. As between daily and twice-a-day practice, the latter is much more effective if we consider the time elapsing since practice began. But, of course, there are twice as many actual hours of practice.

In the case of concentrated practice, the question may well be raised whether the later practices on the same day, even though no higher score is made, are not effective in fixing the habit. This point the author tested in the following way. A group of four subjects began in the morning to work all day at a substitution experiment. At the end of the fourth practice period one of the subjects stopped, the others continuing all day. Two and three days later the effects of the practice were determined. The subject who had worked only four periods showed up as well in the retention tests as those who had worked all day. It is clear that beyond a certain point further practice on the same day is profitless, not only in raising the score but in fixing the habit.

In Fig. 12 are shown the results of an all-day substitution experiment performed by the author. The experiment was as follows: Using a symbol alphabet, I practiced transcribing for fourteen half-hour periods with half-hour rests between, continuously throughout

the day from eight in the morning till ten at night. The results are compared with fourteen daily practices of a subject of the same learning capacity as the author. In the concentrated practice in this experiment there is no improvement after the third practice. In the distributed practice, improvement continues throughout.

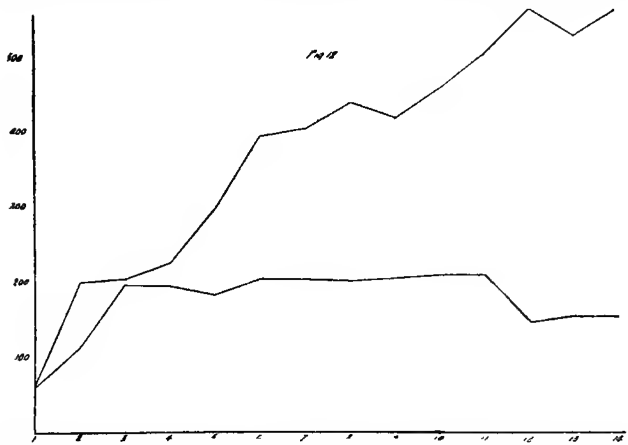

FIGURE 12. The lower graph shows the results of 14 half-hour practices on the same day in a letter-symbol substitution experiment. The upper graph shows the results of the same number of practices, one a day for fourteen days.

We need not report in detail the work of other experimenters bearing on the distribution of practices. In general the experiments of Murphy, Perkins, Chapman, Strong and others confirm the results as stated above. Three facts seem to be fairly certain: (1) In establishing a complicated set of habits as in typewriting, frequently repeated practices at the start are profitable, perhaps as many as three or four half-hour periods a day separated by rests of a half-hour. (2) after habitu-

ation has proceeded further, frequent practices seem not to advance habit-fixation faster, or at least not much faster, than less frequent practices. (3) In processes involving complex motor co-ordination as in javelin-throwing and ball-tossing long intervals seem more profitable. Perhaps different laws are involved in situations in which the goal desired is perfecting a series of complicated muscular movements through the trial and error method. In such work as card sorting, the problem is not to get the hand to make a certain kind of movement. The hand can make all the movements easily enough. The problem is to remember *what movement the hand is to make* for each number of card. In such an experiment as ball-tossing, the problem is to secure the proper co-ordinated movement. We know *what* we are to do, we are not able always to do it.

As far as it is possible to judge from the experiments, brief practices with relatively long intervals are more profitable in cases involving the securing and mastering of unperfected motor movements. More concentrated practice seems profitable in cases where the *actual movement* can easily be made, and where the problem is the connecting this movement with a particular stimulus.

What practical advice should be given to teachers who must determine and direct the practice of children? The practice periods of children should be short, and in most cases, once or twice a day. After habituation has proceeded to a considerable degree of fixation, the practices may be less frequent. By "short," we mean five, ten, fifteen minutes, depending upon the nature of the learning and how fatiguing it is. In general,

practice gives reasonable returns until fatigue has set in. Even though shorter periods and longer intervals would, in some cases, give better returns, it is not usually expedient to use them, because in most cases *we want efficiency* at the earliest possible moment, and can afford to accept a decreasing return for longer practices and more frequent intervals. Even if a second practice on the same day with the typewriter does not give me quite so much return as if I should wait till the next day for the next practice, I should take the second period on the same day if I have the time and am in a hurry to acquire speed on the machine. On the other hand, if I am in no hurry for the speed, and I can use my time profitably otherwise, it would be wise to delay practice till the following day. But if I am in a hurry to acquire the speed, and have nothing else to do with my time, I should practice for about five half-hours a day, at least for a while. In determining the length and number of practice periods, a teacher should consider all the factors. In school, usually there is no special hurry, and there are many things demanding attention, therefore economy of time should have full consideration. This means that one or two vigorous practices a day, daily, is best. The child may, in most cases, continue practice at one time as long as he shows a high degree of efficiency, or in other words, till fatigue effects begin to show themselves. It is certain that in such processes as the elementary operations of arithmetic, practice periods of a very few minutes daily give very high returns. With young children no kind of practice period should be long. For children decreasing returns set in very early.

EXPERIMENTS

The comparison of different lengths of intervals is a work too difficult and extended for a class experiment, but a comparison of different lengths of practice periods may well be undertaken as a demonstration experiment. Two experiments will be described:

1. Card-sorting. Material, card-sorting box and cards for one row of boxes for the check experiment and cards for a different row of boxes for the second experiment.

Method: Have all the members of the class sort cards into one row of boxes for ten times at one sitting. On the basis of the records, divide the class into four groups having equal learning ability, then take a different row of boxes for the second experiment. Have one group sort twice a day for ten days, another group sort five times a day for four days, another group sort ten times a day for two days, and the other group sort twenty times at one sitting. With the same scale and on the same base, plot learning curves for each of the four groups.

2. Substitution experiment. Material, the same as in experiment 1, Chapter II, and an additional key. Method: On the basis of experiment 1 in Chapter II, divide the class into four groups of approximately equal learning ability. Use the same digit-symbol test sheets, but prepare a different key by taking different letters of the alphabet. This key can be supplied to the students, or they can copy it from the blackboard. Work in five-minute periods. One group can work ten minutes a day for six days; another, twenty minutes a day for three days; another, thirty minutes a day for two days;

and the other group, sixty minutes at one sitting. In all cases, keep the individual records for each five-minute period. Plot the learning curves for the different groups as in experiment 1 above.

3. One or the other of the above experiments is perhaps all that can be undertaken in an ordinary lecture course, but if time and opportunity permit, an experiment showing the poor results of extended practice on the same day would be very instructive and impressive to the students. Any sort of learning experiment would suffice. An experiment with the same material as in 1 or 2 above is recommended. To illustrate the procedure, we shall take the card-sorting experiment. Use three rows of boxes that have not been used in an experiment before. Make five sortings at a sitting, with half-hour rests between sittings. The class can be divided into four groups of equal ability as determined by previous experiment. One group can sort all day; another group, three-fourths of a day; another, one-half of a day; and the other group, one-fourth of a day. The division of work might very well be two sittings, four sittings, six sittings, and eight sittings. The results of the experiment should be tested a day or two later, by having all the subjects sort the cards twice, and taking the average of the two sortings as an indication of the efficiency attained.

REFERENCES.

Bradford, C. J., *An experiment in typewriting*, Ped. Sem., xxii, 1915, 445.

Cummins, R. A., *Improvement and the distribution of practice*, T. C. Cont. to Ed., No. 97, 1919.

Leuba, J. H., and Hyde, W., *An experiment in learning to make hand movements*, P. R. xii, 1905, 351.

Murphy, H. H., *Distribution of practice periods in learning*, J. E. P. vii, 1916, 150.

Perkins, N. L., *The value of distributed repetitions in rote learning*, B. J. P., vii, 1914, 253.

Pyle, W. H., *Economical learning*, J. E. P., iv., 1913, 148; *Concentrated vs. distributed practice*, J. E. P., v., 1914, 247.

Starch, D., *Periods of work in learning*, J. E. P., iii, 1912, 209.

Strong, E. K., *Two factors which influence economical learning*, J. of Phil., etc., No. 5, 1914.

Thorndike, E. L., *Notes on practice, improvability and the curve of work*, A. J. P., xxvii, 1916, 550.

Washburn, M. F., and others, *The effect of the interval between repetitions in the speed of learning a series of movements*, A. J. P., xxiv, 1913, 580.

CHAPTER IV.

ECONOMICAL LEARNING.

GENERAL FACTORS.

Attention and Learning.—In the preceding chapter we have discussed repetitions as if their value were a constant thing. In all the experiments on which our discussions and conclusions have been based, we have assumed that the work was done under favorable psychological and physiological conditions. But the fact is that repetitions are not of equal value, and it is now our problem to enquire into the general factors that affect their value. The first and most important of these factors is attention. It will be necessary for us to explain the precise sense in which the term attention is here used. Defined in terms of consciousness, attention means sensory clearness. To say that we are attending to a process is to say that the process is clear in consciousness. It stands out from the other simultaneous processes; it is focal. Physiologically, attentive processes are those that usurp or monopolise the cerebral activity at the time. As a result of evolution, our central nervous systems are so constituted that there is always a synthesis or unification of the various stimulations of the moment for the initiation of action. This synthesis or unification, physiologically, is attention. It is as if we had not one brain but many; but to control action, one of these many brains must

momentarily usurp the function of initiating movement. We have many sense organs. Their constant stimulations are in eternal conflict for the control of action. Now, in learning, the processes which we wish to couple together must be among those processes that for the time are monopolising the cortical energy or, in other words, the processes involved in learning must be in the focus of attention.

It is not so much a matter of definite experiment as a matter of general observation in learning experiments and in life in general that enables us to say that if we wish to learn, we must attend. The processes which we wish to unite through learning must be processes that for the time are monopolising the available cerebral energy. The primary, fundamental law of association is that ideas to be bound together must be *experienced* together in a state of attention. In the sphere of habit-formation, the law seems to have at least wide application, if it is not indeed universal in its applicability.

In all the learning experiments performed in the author's laboratory it has been observed that those learners who carried on the practice with the highest degree of concentration, other factors being equal, made the fastest progress. Now, by a high degree of attention we mean no more than that the processes involved in the learning monopolised the person's activity for the time. The fast learner is tense, the whole body seems devoted to the learning processes, no other process can participate to any considerable degree in the organism's activities while these particular learning processes are in progress. In attentive learning the doors seem to be shut against all other processes.

In inattentive learning, which is also ineffectual learning, the learning processes have successful competitors; they do not usurp the organism's central neural activities. In such case, the practice or repetitions are largely ineffectual in strengthening the neural bonds between stimuli and responses.

In the card-sorting experiments, the fast learners gave themselves over completely to the work. For the time being the world was to them a card-sorting world; nothing else existed; nothing else was for the time of any consequence. The card-sorting completely occupied the central neural activities. Their bodies were rigid and tense, they leaned forward to their tasks, they whispered to themselves the numbers of the cards.

With the slow or poor learners, all was different. Their bodies were relaxed, and many other activities shared the central field of neural activity with the card-sorting performance. They often gazed about the room, listened to the various noises, and watched their associates in the laboratory.

When the fast learner found a box, he deposited the card and then *dwelt upon the location of the box.* He allowed the idea of the location of the box to come into full and focal consciousness, and have a noticeable temporal existence. He might use some device to aid. He might, for example, say "Now I must remember number 14, it is there near the corner just under 19". The idea of location would thereby have more than a fleeting existence, and would also likely acquire some helpful associations.

When the poor learner finds a box the card is dropped into it and before there is time for the idea of location to develop and helpful associative ideas to form, the

subject passes on to the next card, and the whole experience with the card just deposited becomes almost as if it had not been. And when he, a little later, comes to a card of the same number, he must hunt for the box again.

In the early stages of learning to sort cards, sensational and ideational disturbances are fatal. The sensational, perceptual disturbers are such as others sorting cards in the same room, the noise of their performance, their whispering to themselves, the noise of an opening door. Any sensational disturbance tends to prevent the formation of the bonds. Any sensational competitor for focal consciousness, driving out the box-location idea, obliterates the bond between stimulus and response.

Ideational disturbances are equally effective in obliterating or obstructing the bonds which we are trying to form and strengthen. With proper care and precaution we can guard against most of the sensational disturbances but we are powerless to prevent ideational ones. Any ideas foreign to the learning process will disturb. For example, if a subject is doing well, and the idea comes, "now I am doing fine," this idea interferes, he forgets the box-locations and the score is lowered.

Sensational disturbers or distractions can lose their force. We can become adapted to them. As a rule, constant environmental factors become as if they did not exist. It is therefore necessary in a comparative learning experiment to keep all external conditions constant. We must have the same persons sit in the same places, and all persons and things in the room must maintain the same relative positions in successive ex-

periments. If a person is used to working with a group, then not to have the group present is a distraction. On the other hand, if a subject is used to working alone, the group will disturb. Great importance often attaches to apparently insignificant factors. We can not ignore the details of time and place, the method of starting the experiment, the arrangement of the apparatus, the place in the room or about the table where the person works. Even the general attitude of the experimenter and his tone of voice are important factors and must be kept constant.

In Geissler's important attention experiments it was found that the best adding records were made under conditions of distraction. This seems paradoxical, but is really in harmony with the principles laid down above. The subjects in Geissler's experiments had distraction series and no-distraction series. In a no-distraction series, the subject said, "Oh, this is easy, I can take my time". He would consequently relax and leisurely perform the adding, making only a moderately fast record. But if it was a distraction series, the subject took a different attitude. He said, "Now, this is difficult; this will take all there is of me." He became rigid, tense, used every known device to give the adding processes the right-of-way and keep the distracting stimuli out. As a rule, he was successful. The distracters did not really distract; they were not able to become focal; they beat in vain at the gates of central neural activity.

Attitude and Learning.—The relation of attention to learning is fundamental. Several other factors that affect the rate of learning, probably produce this effect, in most cases at least, through their effect on attention.

One such factor is *attitude.* The subject's attitude toward the work of a learning experiment is one of the most important factors determining progress. If for any reason the subject dislikes the work, progress is slow; little effort is put forth; the subject works in a poor state of attention to the work. There is no ambition to do well. The subject is content to make poor records, for in his opinion the work is of no consequence, and it therefore is no disgrace to do poorly in it. It often happens that poor records at the beginning are the cause of the dislike. The dislike in turn becomes the cause of more poor records. Poor work and bad attitude reinforce and perpetuate each other.

A bad attitude retards learning, but just as surely a favorable attitude accelerates learning. The subject who likes the work seems able to give himself over more fully and completely to the work than one who dislikes it. Good records at the beginning of an experiment often are the cause of a favorable attitude. The person does well in the work and therefore likes the work. The favorable attitude caused by good records becomes itself the cause of more good records. It therefore turns out that the good become better and the poor become worse. In learning we have an example of the law that "To him that hath, shall be given and from him that hath not shall be taken even that which he hath".

Peterson reports a class experiment which shows the effect of attitude. A list of words was put on the blackboard and then copied by the students of the class. An immediate reproduction was called for and also a delayed reproduction. The experiment was repeated in the same way except that the students were told

that a reproduction would be called for. In the experiments in which the students knew that a reproduction would be called for, the immediate reproduction was 14.8% better for one section of students and 30% better for the other section. The delayed reproduction was 48.4% better for one section and 51% better for the other. The difference in attitude made a very great difference in the results. When the students knew that a reproduction would be called for, they paid more attention to the words, kept them in the focus of attention longer, said them over to themselves. When one knows what is to be expected of him, he directs and controls his attention and observation accordingly.

A somewhat similar result is shown by the experiments of Ordahl. Her experiments showed that if objects appeared in the field of vision but were not attended to, they were no more easily learned later than if they had never been seen. It is evident that in ideational learning, objects must be in the focus of attention. Attitude has much to do in determining whether a process shall be focal or not. We usually see what we look for. In learning experiments I have often read the same passage over and over again to different subjects. The subjects, one after another, would learn the passage, while I would not, although I had read it to many subjects in succession, each of whom had learned it. The reason I had not learned it was because of attitude. I had not tried to learn it.

The importance of the attitude of school children is certainly very great. If they are to learn effectively, they should be favorably disposed toward the teacher, toward the school, toward the various school subjects

and toward the specific task or lesson. If the child likes the school, the teacher, and the particular work, fast progress is assured if other factors are favorable. Dislike of the school, the teacher or the task works against progress. When a favorable attitude on the part of the pupil is secured toward the various aspects of school life, successful learning is assured, as far as the pupil has ability to learn. On the other hand a pupil that has a dislike to the school, the teacher, or the particular work, proceeds under a very great handicap. A year of school is wasted for many a child because of such dislike. One of the teacher's greatest problems and duties is to secure a favorable attitude on the part of those to be taught.

Life Bents or Dispositions.—Attitudes may be temporary or permanent. In the latter case they may be called life bents or dispositions. We can become favorably disposed toward a certain study as history, a certain principle as evolution or democracy, a certain method as that of analysis. These favorable dispositions foster their own growth and perpetuate themselves, becoming permanent dispositions. They make learning easy in certain narrow directions, and difficult in others.

Definite attitudes are often formed early in life. These attitudes then may affect all future learning. A child because of having a poor teacher, because of getting started in a wrong way, because of starting too early, or for some other reason, may have a dislike for arithmetic. Because of this dislike, he studies it as little as possible, putting his time on studies that are liked. He therefore makes little progress, and this makes mastery ever more difficult and increases the

dislike. Progress in arithmetic continues to be slow because of the unfavorable attitude and because of the poor work done in it before. In a similar way a pupil may acquire an unfavorable attitude toward any of the school studies. These facts make clear the importance of beginnings, the first day in school, the first experiment with the teacher, the first lesson in any subject. School work is hard at best and should not be made harder by means of unfavorable experiences.

The learning of lessons or any other assigned tasks should never be used as forms of punishment. Children should never be kept after school as a form of punishment. The reason that such practices are wrong is because such procedures create dislike for things that should be liked. They create unfavorable dispositions and attitudes that make learning difficult. Failure to take account of these simple principles is the cause of many a failure in the school-room, and the cause of many a wasted life.

Incentives to Practice.—Attention is the fundamental condition necessary to learning, and attitude may be considered a permanent state of attention, or readines to attend to a certain type of process. The practica problem is how to secure attention and permanent dis positions. There are various factors or elements whic we may discuss under the head of incentives.

(1) *Knowledge of the End Sought.*—If the learne can be made to see the end sought by practice, learnin is usually facilitated. This facilitation comes through better attention and more favorable disposition. Fe people are willing to work blindly. Exactly what is t be gained by a habit and exactly what the habit is should be made clear to the learner. In addition, fo

example, the immediate end sought is to be able to pronounce the sum immediately upon seeing the numbers. The skill when attained enables us to add the scores in a game, our money, our account, etc.

(2) *Knowledge of the Score.*—Knowledge of one's record is a material factor in progress. If a learner keeps a close and accurate record of his progress, it incites him to practice at the highest efficiency. Without a knowledge of results, one usually practices on a level much below the maximum. Teachers should find accurate means of measuring the progress of the pupils. The improvement from day to day and from month to month should be shown to the children. They should be taught to make and interpret learning curves, and should plot their own curves.

Arps furnishes some experimental evidence of the effects of a knowledge of the results of practice. Using the Bergstrom ergograph, he took series of records in which the subjects were shown their records. He took other records and gave the subjects no knowledge of their records. In the case of work with knowledge, the results were 18 per cent. better than in work without knowledge.

Wright, also working with the ergograph, used as an incentive the ambition to reach a certain standard of work. The students were shown their records. More work was accomplished with the incentive than without it. If an impossible limit were set, the total amount of work was decreased. Fatigue was found to be less when the subject worked with the incentive.

In ordinary school work, the pupils work on blindly, not knowing—or caring—what they are aiming at, nor what it will be when attained; they do not know what

progress they are making; they do not know what progress is possible nor what attainment is finally possible. When they go on the playground to play, the situation is entirely changed. There is something definite to be attained. They engage in running or jumping matches, let us say. They know how fast they can run and how far they can jump. As a rule they know it very accurately. They know who among them is best and how much he is best. They know the established records in the various sports. They know how much they themselves have improved since the year before. The performances are definite, the methods are definite, the results are definite and definitely known. Inside the school-room, everything is vague and indefinite. Everything is imposed from without. There is little inward impulsion or desire as there is on the playground. Definite knowledge of progress made by the pupils is one means of improving the work inside the school-room.

(3) *Knowledge of Errors.*—Not only should children and all learners know the results attained, they should also have definite knowledge concerning their mistakes. In that type of learning in which errors are possible, unless one knows his errors he may practice on indefinitely with little or no improvement. Experiments have shown that in such tasks as mirror writing and prismatic writing, knowledge of the erroneous movements are necessary to progress. In spoken and written language, as Thorndike has pointed out, one may go on practicing indefinitely without improvement.

(4) *Knowledge of When the Material Learned Is to Be Reproduced.*—If one knows when learning, that the matter learned is to be reproduced, immediately or

later, he proceeds differently in his learning. He takes a different attitude, and the learning is more efficient.

These four points may be summarised as follows: Learning can be improved by giving the learner a definite idea of the nature of the habit or the end sought by learning and the advantage that is to come to him from possessing the knowledge or habit, by a definite knowledge of the progress made and of the mistakes, and by a knowledge of the use—immediate or delayed—that is to be made of the results of learning.

Definiteness of the Bond.—In some kinds of learning it is difficult to use the principles set forth above because of the indefiniteness of the nature of the bond to be formed. Progress is always easier when the nature of this bond can be definitely and clearly known. In mathematics, for example, the nature of the bond is always clear. In all the fundamental operations of arithmetic, the bonds can be definitely known: $9+8=17$; $6\times7=42$; $\sqrt{81}=9$; $(13)^2=169$. All this is definite and practice can be to the point. The end sought is known, it is definite; mistakes can be accurately pointed out, there is never any doubt about the matter; progress can be accurately and definitely measured. But it is not so in writing, drawing, or English composition. In writing, it is true, a copy can be set, and the child can know what sort of result is expected, but just what he is to do to achieve that result, he does not know and no one can tell him. All he can do is to keep on trying. If his product is not like the copy, it is often difficult to say what the difference is. Sometimes, we can get at it approximately. We can say a letter is too high, or too low, or too narrow, or too wide. In drawing we have precisely the same difficulties, so also in learn-

ing to write good English. When a pupil writes an English composition, it is difficult for the teacher to point out exactly what its defects are. But progress by the pupil is possible only to the extent that the defects can be pointed out. To illustrate: A particular sentence may not be clear, it may be ambiguous. Such defects can be pointed out, and just *why* the sentence is not clear must be shown, just *wherein* it is ambiguous must be pointed out.

In all subjects in which the nature of the bonds to be formed is more or less indefinite, teaching is likely to be loose and vague, and the results uncertain. When we can not know exactly what we are seeking, it is impossible to measure our approach to the thing sought. When an English theme is handed in we cannot indicate either its excellencies or its deficiencies as we can when the solution to a problem in mathematics is handed in. In English, therefore, and in all subjects in which the same situation exists, teaching can never have the definiteness that it does in science and mathematics. English teaching is vague still in another sense. Different teachers have different ideas as to what is to be attained and put different estimates on the value of a literary product. There can be little difference of opinion as to whether a problem is solved correctly. There can be much difference of opinion as to the merit of a composition.

Franklin gave us two good examples of definiteness in practice. One was in the field of ethics and the other in the field of English. His clear insight and farsightedness enabled him to see that one must go about improvement in any field in a definite, systematic and

methodic way. He knew that character was dependent upon habits. He knew that he could not merely resolve to be good and immediately make improvement in all aspects of his character. So he made a list of the desirable virtues and practiced on one for a time, then added another, then another, and so on till he had included all the virtues. Then he went all over the whole scheme again. To improve his English, he memorised certain material in the *Spectator*. After he had forgotten the words, he wrote out the thought in his own words. He then compared his expression of the thought with the expression in the *Spectator*. Here was something definite. On the one hand, he had his own expression of a thought; on the other, he had the expression of the same thought by one of the best writers of the time. He could compare them. He could see wherein his writing was poor.

By being more definite and specific there is possibility of improvement in our teaching, whatever we may be teaching. We should make careful analysis of the material which we are teaching, and come to a clear understanding of it ourselves and then make it clear to those taught. We must have a definite goal, a definite route to travel to reach it, and a definite means of knowing when we have arrived. Learning must cease to be a travelling by an unknown route to an unknown place.

Feeling and Learning.—The relation of feeling to learning may be discussed from two points of view. Feeling is important in securing practice, and in making practice effective through attention. Feeling and attention are different aspects of the same thing. When processes are pleasant, we wish to experience them. To

say that we like a thing is about the same as saying that we shall attend to it. Attention is necessary to effective learning. Feeling is necessary to attention. Most of the importance of attitude previously discussed, depends upon favorable disposition, and favorable disposition depends upon pleasurable experience. If a child begins to form a habit and for any reason the processes are accompanied or followed by pain, then the child does not want to practice again. Feeling is therefore an important element in learning because without accompanying or resulting pleasure we do not like to practice, and when we do practice, do not throw our whole selves into it. Pleasure accompanies experiences of which we wish more, experiences that we seek. Pain is connected with experiences which we wish to avoid. Briefly, pleasure leads to practice and makes practice more profitable. It leads to practice because we like to do things which give us joy. It makes practice more profitable because it insures a higher degree of attention. From the point of view of securing effective practice we must take great pains to make conditions such that practice will be pleasurable.

Thorndike claims that pleasure has still another relation to learning, namely, that it stamps in the process. If the passage of a stimulus over to its response is accompanied or followed by pleasure, this pleasure has an effect upon the nervous path which results in strengthening the bond,—so the argument runs. The recent work of Kline gives some warrant for the contention. Kline found that the pleasure accompanying movements helped to fix the bonds.

Snoddy, however, in a recent "Experimental analysis of a case of trial and error learning in the human sub-

ject," claims that the pleasure resulting from a movement has nothing to do with stamping it in, but he gives no conclusive evidence. He points out that in his experiment—the mirror tracing of a star—improvement followed a recess or rest period. "From such evidence," he says, "it is readily seen that no selecting agent, such as 'satisfyingness of a response' is operative to 'select out' the successful responses made in a series of random movements—the basis of Thorndike's view, since the successful responses did not occur in the tracings before recess [rest] period." But Thorndike never claimed that pleasure could stamp the bond in *before its formation.* After the rest periods, successful movements or tracings were made. Thorndike's view is that the pleasure resulting from the successful tracings is a causal element in fixing these movements for the future. And Snoddy gives no evidence to prove that satisfaction had nothing to do with stamping them in.

The fact is that the experimental evidence available does not enable us to say whether the physiological correlate of pleasantness is a causal element in fixing a bond once secured. It certainly does not enable us to say that it is not, and the physiological facts at present known—facts concerning the nature of pleasantless and unpleasantness—rather support the Thorndike view that pleasure is causally effective.

Recent psychological and physiological investigations into the nature of feeling and emotion make it clear that pleasantness and unpleasantness have far-reaching and fundamental effects upon the body which must profoundly affect learning, in ways other than merely securing attention or stamping in the process. Pleasant-

ness has important positive relations to general well-being, and specifically to digestion and nutrition, also to cardiac activity and to neural activity. Unpleasantness produces in general the opposite effects. Pleasantness heightens and facilitates all positive, healthful, life-giving functions of the body. Unpleasantness is negative. It retards, inhibits, constricts. Pleasantness makes for more of life; unpleasantness makes for less of life. It is therefore clear that pleasantness is a necessary condition of learning, and that unpleasantness retards learning.

It will be wise for teachers to bear these facts in mind, and use all available means to make the learning processes pleasant. The age-old practice of rewarding the child when it does what we think it ought, and of punishing it when it does what we think it ought not, has sound scientific justification. The Montessori principle of using great care to prevent unpleasantness from becoming attached to learning, is also sound. So important is the matter of attitude and feeling in learning that we may say that attention, favorable attitude and pleasantness are the absolute essentials of economical learning.

But while pleasantness facilitates learning, any intense emotion of whatever kind is unfavorable to learning. This statement is based upon general observation of the effects of intensive emotions on a learning subject and also upon the results of physiological studies. Cannon says: "Any high degree of excitement in the central nervous system, whether felt as anger, terror, pain, anxiety, joy, grief or deep disgust, is likely to break over the threshold of the sympathetic division and disturb the functions of all the organs which that division innervates."

Violent emotions prepare the body for intensive muscular activity. To quote Cannon again: "Muscular action is made more efficient because of emotional disturbances of the viscera. The cessation of processes in the alimentary canal; the shifting of blood from the abdominal organs; the increased vigor of contraction of the heart; the quick abolition of the effects of muscular fatigue; the mobilizing of energy-giving sugar in the circulation—every one of these visceral changes is directly serviceable in making the organism more effective in the violent display of energy which fear or rage or pain may involve." The violent emotions prepare us for violent muscular activity but not for learning. The conscious processes accompanying the various physiological changes listed by Cannon would always be focal in consciousness to the exclusion of learning processes.

EXPERIMENTS AND EXERCISES.

1. Object, to study the effects of distracting the attention of a learning subject. Material, digit-symbol test sheets, two different keys. Method: Divide the class into two equal groups. Let one group do a five-minute practice under distraction, then a five-minute practice without distraction. Let the other group do first a non-distraction practice and then a practice with distraction, five minutes each time. The keys should be used in the same order by the two groups. If the groups are small and are not known to have the same learning capacity, they should do a substitution experiment with a different key under the same conditions. Find the average performance of the two groups under distraction and without distraction. The in-

structor can determine the form of distraction to be used. Some form of auditory distraction will probably be found most convenient; for example, a continuously ringing electric bell, or a distraction suddenly introduced.

2. Object, to study the effects of directing the attention of a learning subject. Material, ten cards with a word printed in the middle of each, with a color at the top and a number at the bottom. The colors should all be different and the numbers different. Method: Say to the subject that you will show him in succession, ten cards with a word printed in the middle of each, and that he is to write down the words after the ten have been exposed. Expose the cards very quickly, giving just time for the words to be clearly seen. After the exposure, ask the subject to reproduce the colors and numbers instead of the words, and compare the results with the reproduction of the colors and numbers when the attention is directed to them. This experiment can be given only to subjects who are unacquainted with its purpose.

3. Further experiments on the effects of attitude can be devised by the instructor or students. For example: Select a short poem and read it aloud to a learning subject. Determine the number of repetitions required for the poem to be learned. Then read the poem to other learners till each has learned it. If you have not *tried* to learn it, you probably can not reproduce it although several persons have learned it while you have been reading it. Repeat the experiment with a different poem, and try to learn it while your subjects are learning it. The effects of attitude will be evident.

4. The effects of knowledge of errors can be studied by means of an experiment in which some form of concealed hand movement is required. Compare the results when the subject is ignorant of his errors with the results of other subjects who are shown their errors. The movement can be such as placing a pencil at a certain angle with the perpendicular. The details should be planned by the instructor.

5. The effects of attitude and consciousness on learning can be further studied by means of experiments modeled after those of Ordahl and Peterson. See the references.

REFERENCES.

Arps, G. F., *A preliminary report on work with knowledge vs. work without knowledge of results*, P. R., xxiv, 1917, 449.

Boswell, F. P., and Foster, W. S., *On memorising with the intention permanently to retain.* A. J. P., xxvii, 1916, 420.

Chapman, J. C., and Feder, R. B., *The effect of external incentive on improvement tested in addition*, J. E. P., viii, 1917, 469.

Conrad, H. E., and Arps, G. F., *An experimental study of economical learning*, A. J. P., xxvii, 1916, 507.

Dallenbach, K. M., *The effect of practice upon visual apprehension in school children*, J. E. P., v, 1914, 321 and 387; *The effect of practice upon visual apprehension in the feeble-minded*, J. E. P., x, 1919, 61.

Ordahl, L. E., *Consciousness in relation to learning*, A. J. P., xxii, 1911, 158.

Peterson, J., *The effect of attitude on immediate and delayed reproduction*, J. E. P., vii, 1916, 523.

Rich, G. J., *Directed attention and learning*, J. E. P., viii, 1917, 239.

Smith, F. O., *The effect of training in pitch discrimination*, P. R. Mon., No. 69, 67.

Snoddy, G. S., *An experimental analysis of a case of trial and error learning in the human subject*, P. Mon. No. 124, 1920.

Wells, F. L., *Practice effects in free association*, A. J. P., xxii, 1911, 1.

Whipple, G. M., and Curtis, J. N., *Preliminary investigation of skimming in reading*, J. E. P., viii, 1917, 333.

Wright, W. R., *Some effects of incentives on work and fatigue*, P. R., xiii, 1906, 23.

CHAPTER V.

ECONOMIC LEARNING.

SPECIAL FACTORS.

In the preceding chapter we considered the fundamental factors that influence learning. We shall now consider a number of specific factors that have a bearing on economical learning. The ultimate explanation of the specific factors is to be found, in most cases, in the more general and fundamental principles already discussed.

School Room Drill.—Habits can be established only through repetition. Knowledge can be organised and fixed for permanent and practical use only through thinking it over, by bringing the ideas to consciousness again and again. The school undertakes to establish a great number of essential habits in the pupils, and to help them acquire and organise a great body of knowledge. There are writing habits to be formed, spelling habits, reading habits, language habits, arithmetic habits and a multitude of social, moral and conventional habits. This work takes most of the time of the school. The public school in this country originated as a place where the education of the home was supplemented by drill in the so called three R's. As the years have gone by, the school has enlarged its function and taken over nearly the whole work of the education of the child. It is not our purpose here to go into the general question of the socialisation of the school, and its other modern developments. We shall consider only one aspect of this development.

Certain modern educational reformers have undertaken to dispense with formal drill altogether. Their notion is that the child will incidentally get enough repetition to fix the fundamental habits. In such a scheme, spelling, writing, arithmetic and even reading are not taught as such specifically. The child writes letters and essays and in writing them gets practice in writing and spelling. The child is never drilled in the fundamentals of arithmetic, but he solves concrete problems and in doing so gets practice in the use of the fundamentals.

The problem of formal versus incidental drill is really an experimental one. It can not be settled by argument but only by an appeal to the facts. One of the primary principles of learning is, *there must be repetition.* For learning to be economical, the repetitions must be under the general conditions of economical learning already discussed. Any procedure that secures practice under these principles is psychologically sound. We have therefore to compare the results of repetition that is merely incidental with the results of repetition that is specific or formal. There are several studies that touch upon the problem.

Drill in Arithmetic.—In 1911 J. C. Brown reported an experiment in which he had undertaken to determine the effect of drill in arithmetic. He worked with children whose average age was thirteen and a half years. He divided them into two groups of equal average ability in arithmetical operations. One group of twenty-five pupils was given five minutes of daily drill in the fundamental operations of arithmetic for thirty days. The other group of twenty-six pupils may be called the control group. It did the same work in

arithmetic as the drill group except that it had no formal drill in fundamentals. The only practice it had in the fundamental operations of arithmetic was what it got in solving the regular problems. At the end of thirty days the groups were tested and the drill group was found to be 21.2 per cent. better in the number of problems solved, while the non-drill or control group was only 9.8 per cent. better. After a twelve weeks vacation, the groups were again tested and it was found that the drill group maintained its superiority.

Brown later repeated his experiment using 222 pupils whose average age was 12.2 years. The drill was in arithmetical fundamentals as before and continued five minutes a day for twenty days. The drill group improved 16.9 per cent. while the non-drill group improved only 6.4 per cent. This second more extensive study therefore corroborated the results of his first study.

Thorndike in 1910 and Donovan and Thorndike in 1913 reported some experiments which show the value of school room drill in arithmetic. In one experiment, twenty-nine fourth grade children were drilled two minutes twice a day for fifteen days—sixty minutes practice in all. They improved from two and three-fourths examples per minute to four and a half a minute, showing the great effects of practice.

Phillips reports (1913) an experiment with sixth, seventh, and eighth grade children. He divided them into a drill and a control group. The drill group had ten minutes a day practice for two months in arithmetical fundamentals and in reasoning. The drill group gained 15% more in fundamentals and 50% more in reasoning than did the control group.

Winch, while studying the problem of the transfer of training, obtained evidence of the great effect of drill in arithmetical fundamentals. He made several extensive studies, in every case dividing the pupils studied into a drill group and a control group. I give the results of two experiments which may be taken as typical.

(1) Thirty-three pupils, ten years old, were drilled in arithmetical fundamentals thirty minutes a day for ten days. As a result of the drill they showed an improvement of 21% in numerical accuracy. The basis of the comparison was the improvement of the last two practices over the first two.

(2) Thirty-two boys, ten years and three months old, were given ten daily practices of thirty minutes each, and as a result showed an improvement of 45.5% in numerical accuracy.

In these experiments, the control group did no mathematical work whatever. While the drill group was practicing on arithmetical fundamentals, the control group studied English in one case and drawing in the other. The drill group did no mathematical work except the drill of the experiment. Winch was interested only in ascertaining whether the drill made the pupils better in arithmetical reasoning. He was not, therefore, able to compare formal drill with incidental drill, since the control group did not have any drill of any kind during the experiment. The experiments do show, however, the very remarkable effects of a few hours of drill.

The experiments leave no doubt of the great effect of even very short drills daily in the fundamentals of arithmetic. It seems clear that besides the regular

work in arithmetic, that of learning the principles and solving problems, pupils should be given short, vigorous drills on fundamentals and perhaps also in solving easy problems mentally. The returns from such drills are enormous. Not only do drills in fundamentals give ease, facility and confidence in their use but make the solving of concrete problems easier because, since the pupils have mastered the fundamentals through drills, their energies are all available for the solution of the problems. The earlier experiments of Winch gave some experimental evidence for the above statement, but his later experiments did not. However in his experiments, the pupils did not actually solve the problems, they only indicated the solution. If they had actually performed the operations, the effects of their previous drill in fundamentals would doubtless have been evident.

Drill in Other Subjects.—Wallin's studies in the Cleveland schools showed the value of spelling drills. He says, "It is by no means evident that modern pedagogy demands the substitution of incidental spelling instruction for the spelling drill. It is still less evident that the schools have outgrown the drill in the other formal branches of the curriculum."

Peters made a study of the influence of speed drills upon the rate and effectiveness of silent reading. He gave speed drills for a period of seven months to grades three, four, five and six. Grade three is omitted from his results. Two hundred and seven pupils took part in the experiment. In each grade, there were two drill groups and one control group. The drill groups took five to ten minutes of the regular reading period for drill in rapid silent reading. The drill group at the

beginning of the experiment read 83.8% as fast as the non-drill group; at the end of the experiment the drill group read 107.5% as fast as the non-drill group. The pupils that were trained in rapid reading therefore improved 18.7% more than did the control group, and this improvement was not at the expense of quality, which, according to Peters, was not materially affected. The experimenter says his result "strongly suggests the advisability of giving speed drills as a part of the teaching of reading", and says further: "It is also probable that it is worth while to teach children to skim."

Whipple and Curtis made a specific investigation of skimming in reading. They seemed not to be concerned with improvement in skimming through practice, but rather in a comparison of skimming with other methods of reading. It is impossible to determine from the published report of their study how much their subjects improved by practice. The experimenters conclude, however, that "It seems probable that practice in skimming might profitably be given in the public school."

Thorndike reports three experiments showing the great improvement of adults resulting from a relatively short period of practice. I give the results of one of these experiments. Ten hospital nurses, 21 to 35 years old, were given 2 hours and 25 minutes of practice, five minutes daily except Sunday, in adding one place numbers. The results are shown in terms of the number of one-place numbers added in five minutes. The first number of each pair represents the initial ability and the second number represents the ability after practice. 180-230, 200-430, 225-368,

225-460, 290-540, 150-280, 220-380, 235-570, 250-440, 260-540. This makes an average improvement of 88.7%.

Some Miscellaneous Factors Influencing Drill.—Conard and Arps compared two methods of drill in arithmetic. They divided 76 high school pupils into two equal groups by the Courtis tests. One group was drilled for eight periods on arithmetical fundamentals, by the traditional method; the other group was drilled for the same time, but their method was to name only the results. For example, instead of saying "six plus four are ten", they simply looked at six and four and said "ten". The latter group showed a great saving of time. In every school subject, the best and most economical procedures or methods for doing the various processes should be experimentally determined, then these processes and procedures should be followed.

Kirkpatrick compared two methods of learning to multiply. He had two groups learn to multiply by using a table. One group memorised the table, the other group used the table from the beginning. The latter method proved the most advantageous. Kirkpatrick draws the following conclusion from his study: "The results indicate that in many lines of teaching there has been a tremendous waste of time, energy, and interest in first memorising, then later practicing the use of what has been learned." It is not economical to acquire skills too far removed from their practical use in life. I have performed an experiment in card-sorting which gives results similar to those obtained by Kirkpatrick in multiplication. The experiment was as follows: Two subjects worked an hour a day for two days sorting cards into five boxes. On the first

day, one subject sorted cards for the whole hour, the other subject, instead of sorting, studied the boxes trying to learn their locations without sorting cards into them. On the second day, both sorted the cards into the boxes. By repeating the experiment several times, having first one subject study instead of sort, and then the other, it became quite evident that the most economical way to learn to sort cards *is to sort them.* Studying the boxes for an hour made learning progress on the next day faster than it would have been without study but not so fast as when the first hour had been spent in sorting.

Chapman studied the effects of various forms of external incentives on the drill effects in adding, cancelling out and in the digit-symbol test. The incentives used were knowledge of previous records, the learning graph, and credit rewards. The motivated group did much better except in cancelling out. In the latter no incentive was needed.

Practice in Fundamental Mental Functions.—We shall now turn from the question of strengthening bonds by practice to the question of the general improvement of a function by practice. This is a wholly different problem from those we have been considering. We take up the question here because certain mental functions or capacities may be considered the tools or machinery of learning. The various forms of sensory discrimination, for example, are necessary elements in many forms of learning. The question of whether these functions, important as elements of learning, can be improved by practice is therefore a vital one. If there are mental functions which are important in all learning, and these functions can be improved by

practice, then we can improve a person's general learning capacity. We turn to the experiments.

Training in Pitch Discrimination.—Studies in pitch discrimination by F. O. Smith in the University of Iowa indicate that there is no improvement from practice. He studied children of all ages as well as adults. As a result of his extensive investigations he makes the following positive statement: "The sensitiveness of the ear to pitch differences can not be improved appreciably by practice. There is no evidence of any improvement in sensitiveness to pitch as a result of practice." It looks as if functions as simple as pitch discrimination are little improved by practice. They depend upon inherited nervous orgnisation. More complex functions seem to be improved by practice at least early in life.

Whipple, by means of a specially devised tachistoscope, gave several adults practice in the range of visual attention and in visual assimilation. He found no improvement after the first few days of work. This early improvement was due to the subjects becoming adapted to the conditions and methods of the experiment.

Dallenbach, following Whipple, made similar experiments, using school children as subjects. Whipple had found that adults made practically no improvement. Dallenbach found that children made considerable improvement. For bright and normal children, the improvement was rapid at first and then slow. For dull and feeble-minded children, the improvement was very slow at first, but continued throughout the experiment. At the end of the experiment some of the dull and feeble-minded children were as good as the average

normal child. Two conclusions seem warranted. (1) In fairly simple mental functions, improvement is possible in the case of children when it is not possible for adults. (2) It sometimes happens that the ordinary situations of school and of life fail to develop even the primary mental functions. In such cases definite, special drill seems to develop these backward functions. Such being the case, although we cannot speak from definite experiments on the subject, it seems likely that the experiences of early life can at least in some measure affect the development of important mental functions. It seems obvious that these functions would not adequately develop without some external stimulation; then surely the character and amount of such stimulation must be of consequence. When the character and amount of stimulation have not been adequate to develop a child to the limits of his natural capacities, then specific drill is highly effective and valuable. When the character and amount of stimulation have been sufficient to bring about the natural growth and development of the various aspects of mental capacity then specific practice with a view to develop mental capacity is of little value. It is of little value because the development has already taken place.

Practical Inferences.—What practical advice shall psychology give the teacher on the question of drill? The experiments leave no doubt of the great value of specific drill, of direct practice. By far the larger part of elementary school work is concerned with habit-formation. The formation of these habits should be faced squarely and directly. If a boy wishes to learn how to pitch balls, he *pitches balls*, not once or twice, but in-

cessantly, day after day, month after month, year after year. We should follow a similar procedure in the case of spelling habits, reading habits, and all other habits to be acquired in school. Is there a certain skill that it is desirable I should possess? Then I must practice, practice, practice. By and by I shall have the skill. There is no reason why we should beat about the bush, evade, or come at it indirectly. I must know exactly what the skill is, have some good reason for desiring it, then I should practice it vigorously, regularly, directly. The school room, for the early years of child life, should be a drill room. The drill periods should be short; the drills vigorous. During the drill, the attention of the children should be of the highest order. They should be working at the highest possible point of efficiency. Usually the drills should be of only a few minutes in length, not long enough to tire the children. Competition, both individual and group, can be used, if used wisely, to advantage. Every known legitimate device should be used to make the practice effective and profitable. particularly should we have the pupil keep his record and plot his learning curve. We should arouse in him an ambition to make the curve rise a little every day. We should show him definitely the skill that is possible of attainment. He should know about how long it will take him to acquire that skill.

Children delight to practice a newly acquired skill, delight in pure practice apart from the use of the skill in any concrete problem. When a child has, for example, learned how to do long division, he will ask for problems in long division merely for the pleasure of exercising the new skill. It is a fundamental principle of human nature that we like to do what we can do,

particularly what we have just learned to do. This delight in mere exercise can be maintained provided the drills are short as well as vigorous.

Practice in school subjects should not, however, be wholly formal. Every skill is only a means to some end. The skill has no real and permanent value in itself. It should therefore be used in its proper setting. Spelling, reading, writing, arithmetical fundamentals have no value in themselves. They are all merely means to ends that are intrinsically valuable. We must be able to spell and write if we wish to communicate with friends at a distance. We must be able to read to get the pleasure and information that is possible from reading. We must be able to add, subtract, multiply nad divide in order to be able to carry on the actual business of our life. In acquiring these skills, we should certainly use them in their real life connections and settings, but not merely so. If a child writes and spells only when writing a letter, it will probably never write a letter. If a base ball pitcher pitched only in games, he would never win many games. Much practice must be preparatory, anticipatory. Early life is preparatory. Nothing can change that fact. Nevertheless, there should be much incidental drill. Situations should be devised in school and in the home that duplicate or mimic life situations, such as keeping store with its buying and selling and calculations and computations. There should also be much letter writing, actual as well as fictitious. The child should have much practice in using his newly acquired skills in their proper settings. But he should have additional practice of a direct and formal sort also. The two procedures combined will give the efficiency which the situations of life demand.

Definite Procedure.—The thing about habit-formation that should be made clear is this: The teacher should understand definitely and clearly what she is trying to do, the knowledge she is to help the pupils to acquire and the habits she is to help them to form. These facts should be clear and definite to her. And she should make definite and systematic plans for the work. The school work of the past has been too indefinite, too hazy, too nebulous. Too often neither pupils nor teachers knew where they were going. Objectives must be known and clear. They must also be as close as possible. There must be constant realisation of aims. We can not put off all realisations, all fruits, all rewards to an uncertain future date. We must set a certain skill to be attained this week, perhaps even in this single practice. Not only must ends be definite and clearly known, but the time and place and manner of practice. By means of the standard tests she done at any time is too often done at no time. The teacher should therefore supervise in great detail the whole work of practice on the part of the pupils, what work is to be done at school, what at home, the exact times of practice, the lengths of periods, the manner of practice. By means of the standard tests she should measure the progress of the pupils. Not only should all these things be definite and clear to the teacher, but they should be clear to the pupils as well. The pupils should know what they are doing and why they are doing it. They should know the precise nature of the habit they are to form, what it will be worth to them when they have it, how they are to proceed to acquire it. And, as already pointed out, they should plot the course of the voyage they make in the

process of acquirement. Not only should teacher and pupils have a clear understanding of their aims and their means of attaining them, but parents should have this knowledge, too. Teacher, parent, and pupil are all working together for the accomplishing of the one definite, clear-cut purpose. Too often the parents do not know, more often still, do not understand the purposes of the school. Under such circumstances they can not properly co-operate. It must not be forgotten that the schools are *maintained by the parents for their children.* It sometimes looks as if schools were maintained by teachers for teachers, that pupils are important only because it is hard to have school without them, and that parents have no importance at all. Their wishes are not to be considered. So easy it is to lose proper perspective and to forget the proper relations of things.

Developing General Ability.—It does not seem that the school can do much toward developing general capacity. There need be no training in the use of the senses. Nature provides for this training in the ordinary course of life. Probably most of the simple, elemental forms of mental activity need no specific training. It may be that in some cases they do, in case of exceptional children; generally they do not. The various aspects of association, learning, remembering, attending get sufficient practice for their development in the process of forming the needed habits, and acquiring the necessary knowledge. Briefly, we do not need to have studies or practices whose purpose is the development of the mind. The life that we must necessarily live develops about as far as development is possible.

We do not mean to say, however, that mental functions develop without reference to the stimulation of

the environment. On the contrary, the development of mental functions is absolutely dependent upon environmental stimulation. What we do mean to say is that the ordinary stimuli which are fairly constant to all human environments are sufficient to bring about normal mental human development. No doubt extreme differences in this environment can measurably influence human development. The evidence of the neurologist supports this view. Burnham*, for example, says, "We see from the genesis of the nervous system that the one condition necessary for normal development is a rich environment giving plenty of stimulation and freedom for the nervous mechanism to develop in its own way. This seems especially important for the cerebral cortex and its dependent structures. The same thing is emphasized, too, by all the cases of defect where normal stimuli are shut off. In such cases, there is always imperfect or arrested development."

What Amount of Skill Is Desirable?—A legitimate question and a very practical one is this: What degree of skill should we attain in the various school subjects? It is certainly not profitable to acquire great skill in functions that are not to be used for a long time, for unless practice is kept up in the interval, the skill will deteriorate before the time comes for its use. If we are always to consider economy, a skill should not be acquired until near the time for its use. It is certain that much time is wasted in school because we do not take this principle into account. We have the child acquire numerous skills in the hope that some time, somewhere he will have occasion to use them. Many

*W. H. Burnham,—*The significance of stimulation in the development of the nervous system.* A. J. P. 28, 1917, p. 38.

of these skills he will never use, and many others will deteriorate before the time comes for their use. In all of the school subjects we should make a careful study of the skills which they give, and at the same time we should make a study of the present and future need of the child. The skills should be acquired with some reference to these present and future needs. It is certain that in many subjects, the amount that we teach should be cut down, stripped of unessentials. We should make a careful estimate of future needs, and consider the relative nearness of these needs. In mathematics, for example, the general needs are very few, the fundamental operations. These are needed constantly, or at least we can say that in any normal sort of life they should be used constantly. They should be mastered, and carried to a point where they can be used with speed, certainty and facility. The same thing is true of reading to get thought, of spelling, and of writing. There is a minimum of essentials which all normal people should get to a fair degree of mastery. Beyond the minimum of essentials, all other skills should be mastered with reference to the time when they will be needed. As a general rule we should master first the skills that we shall need first. A great deal of time could be saved for the children of the country if competent people would select from the various subjects the minimum requirements of skill that are desirable for all. Whenever the special work which a person takes up requires a skill additional to those already acquired, that skill can then be acquired. The skills acquired for distant and uncertain uses should be few. The immediate demands are too great to substitute for them uncertain future demands. But when future de-

mands are not uncertain they should be provided for at the proper time, and the proper time is the one that is the most economical, provided there are no other factors.

Function of the Teacher.—The relation of the teacher to the learners is a close and important one. Book has enumerated and discussed the various ways in which the teacher can be of service to the pupils in their learning. He gives ten points, which may be condensed into eight, and stated concisely as follows:

The teacher can—

(1) Help pupils to overcome difficulties as they appear;
(2) Help pupils to discover the best methods of study and work;
(3) See that pupils use the most economic methods in forming habits;
(4) Minimise the formation of interfering tendencies;
(5) Help pupils to organise and assimilate details in a natural way;
(6) Provide special incentives to effort;
(7) Make hygienic and environmental conditions of learning favorable;
(8) Develop in pupils an attitude of permanent interest in work.

To these may be added another: The teacher can help the pupils to understand the purpose and nature of the habits to be formed.

EXPERIMENTS AND EXERCISES.

The facts of this chapter do not readily submit themselves to class room demonstration. However, the students might very well make application of the facts to the various branches of the public school. These branches can be examined and the habit-forming

aspects of each determined. The students can then work out a scheme of drill or other form of practice for fixing the habits, and in doing this, provide for the use of the psychological facts that are applicable. For example, let us take arithmetic. The actual number of habits that should be formed in the elementary study of arithmetic can be listed, so many in adding, so many in subtraction, so many in multiplication, and so on. The order in which these habits should be established should be worked out. The use of early habits in acquiring later ones should be noted. After the elementary habits have been provided for, a study should be made of the use and application of these in fractions and percentage. On this basis, a course of study in arithmetic as habit-formation could be made. Let the student make an estimate of the amount of time necessary to master the course outlined.

Take other branches and make similar studies from the point of view of habit-formation. The plans of different students should be compared and discussed.

REFERENCES.

Book, W. F., *The role of the teacher in the most expeditious and economic learning*, J. E. P., I, 1910, 183.

Brown, J. C., *An investigation on the value of drill work in fundamental operations of arithmetic*, J. E. P., II, 1911, 81; also J. E. P., III, 1912, 485 and 561.

Donovan, M. E. and Thorndike, E. L., *Improvement in a practice experiment under school conditions*, A. J. P., XXIV, 1913, 426.

Fulton, M. J., *An experiment in teaching spelling*, Ped. Sem., XXI, 1914, 287.

Kirkpatrick, E. A., *An experiment in memorising vs. incidental learning*, J. E. P., V, 1914, 405.

Peters, C. C., *The influence of speed drills upon the rate and the effectiveness of silent reading*. J. E. P., VIII, 1917, 350

Phillips, F. M., *Value of daily drill in arithmetic*. J. E. P., IV, 1913, 159.

Thorndike, E. L., *Practice in the case of addition*, A. J. P., XXI, 1910, 483.

Wallin, J. E. W., *Has the drill become obsolescent?* J. E. P., I, 1910, 200.

CHAPTER VI.

IDEATIONAL LEARNING.

The Nature of Ideational Learning.—By ideational learning, we mean acquiring knowledge. In the last analysis, as pointed out in Chapter I, there is little if any difference between habit and knowledge. Both depend upon established neural connections. In habit, stimulus is connected with its motor response; in knowledge, idea is connected with idea. In forming habits, neural bonds are established which connect certain stimuli with certain muscular responses; in ideational learning, neural bonds are formed which connect certain ideas with certain other ideas. In habits, the muscular response is the important element; in knowledge, although muscular action may take place, it is not an important element, not an essential part of knowledge. In knowledge, the important thing is *sequence of ideas.* If action takes place, it *follows upon* the sequence of ideas, and has no causal relation with them. In the last four chapters, we have had in mind chiefly habit-formation. In this chapter, our exclusive concern is with ideational learning, the getting of knowledge.

Knowledge and Ideas.—Our first concern is to get a clear notion of the meaning of the words *idea* and *knowledge.* The meaning given to each of these terms is a simple and common-sense one. We shall call our sensory experience with the world, primary experience, and the revivals of sensory experience in the absence of sensory stimulation, we shall call secondary experi-

ence. Sensory experience takes the form of perception; secondary experience takes the form of ideas. Perceptions are the conscious processes representative of the objects of objective experience, sensory experience. Ideas are the conscious processes representative of objects in rvived or secondary experience. To illustrate: Suppose I take a walk through the woods. I see, hear, touch, smell, and taste various things. I have primary, sensory, perceptual experience of birds, trees, flowers, fruits, breezes, sounds, temperatures. Afterward, when night has come, I sit in my room and experience the trip all over again in the form of ideas. We shall, then, use *idea* as the general name for the bits or elements of revived experience. We shall use *knowledge* as the name for connected ideas, remembering that one element of the connection may be a perception, but the second element is always an idea.

As I sit in my room and live the wood trip over again, many ideas come to me, not only ideas of the trip but other ideas that come up from every part of my past experience. Within an hour, ideas come, revived from almost every part of my past life. Various experiences of the trip, owing to similarity with past experiences, revive the past experiences, so that the experiences of the trip serve as a means of tapping or sounding almost the whole of past experience. The intricacy with which all of our past experience is bound together is well shown by the free association experiment. In this experiment, the subject is given a word and told to write all the other words which come to mind. The author has the following sequence: sky, sun moon, clouds, rain, umbrella, wet, woman, hat, hair, dress, skin, comb, eyes, glasses, water. Why did these words—representing

ideas—come in this order? In the case of my wood-trip, I find that my ideas correspond to the perceptual experience as it came during the trip, not in strict chronological order, but all the ideas of or from the trip are closely bound together. Do the words, sky, sun, etc., written above, represent any particular experience, or do they come from a great variety of experiences? They, of course, come from a great variety of experiences, and it shall now be our purpose to examine into the laws that determine their coming.

The Law of Association.—Let us suppose that on my walk through the woods, I passed a large boulder and saw a snake coiled up beside it. When the experience comes back to me, I have an idea of the boulder and *also of the snake.* Or, when I go by the same place again and see the boulder I *also think of the snake.* This is typical of all experience. What is experienced together in perception, comes back together as ideas. Processes that take place together in the brain, or come in close succession are connected, they are really a part of one process, as they leave in the brain some form, a trace of this connection, so that later a revival of one of one process, and they leave in the brain some form, a and boulder were together in the woods; they are likewise together in my mind; the creek, and the shore, and the frogs, and the dragon-flies, and water lilies were together in my experience; they are likewise together in my mind. Clouds, and lightning, and thunder, and rain, and mud are together in the world, they set up simultaneous and immediately successive processes in my brain and are consequently together in my mind. Corresponding to all the outer world, with its spatial and temporal and causal relationships, I build up an

inner world of ideas. Whatever relationships and sequences exist in the objective world, hold also with my ideas. The outer world is lawful, orderly, systematic, so also is my world of ideas.

It is obvious that the various objects of perceptive experience are experienced in myriad connections. A horse, for example, is experienced in connection with buggies, wagons, trucks; as being ridden, as being driven; they are seen in pastures; they are seen running away; they are seen dying; they are seen lying on the streets with broken legs; they are seen with colts following them; in a word, they are experienced in a great variety of situations. At any particular time, if *horse* is suggested to me, what one of its ideational connections will follow? Both observation and laboratory experiment have revealed several determining factors, as follows: *primacy,* the original connection; *recency,* the most recent connection. The other factors are *frequency,* meaning the number of times the particular connection has been repeated in perceptual or ideational experience; *intensity,* meaning the intensity or vividness of the experienced connection; and *mental set* or *attitude.* By mental set we mean that the attitude or feeling tone of the original experience is a determining factor in the revived experience. Other factors being equal, the mood or attitude that I am in will determine that sequence, in any given case, which corresponds to previous sequences in the same attitude. At any time, if I see a horse, or if the idea of horse comes to mind, the idea which the idea *horse* will first suggest or arouse, will depend upon the most pervious neural path at that moment, and the most pervious path or connection will depend upon the various strengths of

the factors above mentioned. The first idea may be of a run-a-way horse, depending upon recency, the next idea may be of a horse pulling a plow depending upon frequency, the next idea may be of a horse pulling a buggy depending upon primacy; and the next idea may be of horses pulling a hearse depending upon mood. Always these various factors are at work; always there is a conflict for the determination of the course of association. The path that is most open leads to the first connected idea; the path that has the least resistance next in order determines the next idea; and so on, till the trend of association is diverted by perception or till it is carried internally to another center or matrix.

Thinking.—We shall use the word thinking as a general term to designate the free flow or passage of ideas. This flow or passage depends entirely upon the law of association. While we are awake, there is in us a constant succession of ideas. Usually a perception initiates a series of ideas. For example: I walk along the street. I receive impressions through all the senses. The sights and sounds and odors arouse trains of ideas. I pass a man. His name comes to me. Then I think of various experiences which I have had with him—when I first saw him, when I last saw him, of his business, his family. These ideas are in process when I pass a doughnut shop, which sets up a different series of ideas. The smell of doughnuts makes me think of my childhood, the early home, my mother and her cooking. Nearly everything which I pass as I go down the street is rich in association and sets going a series of ideas.

All day long, wherever we are and whatever we may be doing, we have perceptions. These perceptions set going trains or series of ideas. A closely related series

of ideas leads presently to another. And so the ideas flow along till a new perception breaks in and sets up a different series.

Reasoning.—Reasoning is the flow of ideas evoked by a situation, new or partially new. Since the situation is new, it arouses no response through habitual connections. For all situations that have been repeatedly met, there follow habitual forms of response that have been organised in connection with situations. When we meet a situation partially new and no instinctive or habitual response follows, we have to stop and wait for the associative processes to suggest a solution. The process of reasoning may be illustrated as follows: The outlet of my bath tub was stopped up so that the water would not drain out. The following ideas came to me—there is an obstruction just at the bend outside of the tub, probably there is a way to get in there and get the obstruction out, I look and find that there is. I can get in by unscrewing a nut. But the nut is in a place difficult to get at, and besides I have no wrench handy to unscrew the nut. The pressure of the water in the tub is not great enough to porce the obstruction out. If I should fill the tub full of water perhaps the pressure would be great enough to force the obstruction out. I try it and it will not do it. How can I get greater pressure? The pressure of the water in the water pipes is strong enough to force it out. But how can I utilise this pressure? If I could put a piece of rubber hose on the pipe from which the water passes into the tub and hold the other end of the hose at the outlet of the tub, the force of the water might force the obstruction out. I try it. It will not do it. If I could wrap a rag around the end of the hose at the outlet of the tub so as to force

all the water into the drain pipe, the pressure would be great enough to force the obstruction out. I try it and it works. The obstruction is forced out. The illustration is fairly typical of all reasoning. We meet a situation that has not been met before. The situation suggests or arouses various ideas from our past experience. Certain elements of the situation are like past experiences. An idea comes to us. We try it out. It may work. It may not. If it does not work, it is because we do not have accurate enough information about the forces with which we deal. In the above illustration, I did not know how hard the obstruction would be to force out. I did not know whether the pressure of the tub full of water would be sufficient or not. I had to try and see. Various ideas of getting pressure behind the obstruction came to me. I tried out the ideas till success came.

In the above illustration, an actual situation had to be met. It often happens that we meet a hypothetical situation as when we have to answer a question. The thought processes are the same, but the illustration shows that we can not be sure of an answer to a hypothetical question unless the conditions are accurately stated. Suppose I have a ring of iron and a sphere of iron that will nearly but not quite go through the ring. How can I get it through? Now if my past experience has taught me that heat expands iron, the idea may come to me that if the ring is heated, it will expand and possibly let the ball pass through. If I have accurate knowledge about the expansion of iron due to heat, I can answer the question by making accurate measurements of the ring and ball. If I do not have this accurate knowledge and can not make very accurate meas-

urements, I shall have to try and see, I can not give an accurate theoretical answer. The latter is often the case in our theoretical reasoning. The facts that we have are not full enough and not accurate enough to enable us to make an exact answer. Much of the ordinary reasoning of men has this defect. Much that is taught in school is untrue because due to inferences from incomplete or erroneous data. We have been taught much in physiology and hygiene that is now discovered to be untrue, much about digestion—what we ought to eat, how we ought to eat it and when we ought to eat it—much about diseases, their causes and their supposed cures. All the social sciences are full of false doctrines because of incomplete and inaccurate knowledge. It is so often true that we can not gauge correctly the forces or principles that enter into our reasoning, that we can seldom be sure of our conclusion unless we can put out tentative solutions to the practical test. Reasoning is usually the means by which our past experience suggests possible solutions to the problem or situation which confronts us. The public schools can be of great service to our people and to our country by making these facts clear to children, but this point we must take up in a later paragraph.

There is nothing new about the process of reasoning; nothing different from the ordinary flow of ideas; no new law in operation. The flow of ideas, however, is limited by the situation. We maintain the situation, or external conditions maintain it for us—the water persists in staying in the bath tub—and one series of ideas after another is initiated. Each series of ideas is the result of past experience. Our problem is solved, theoretically, when an idea comes that satisfies us, that

seems in the light of our experience, to fit the situation. The idea may be adequate; it may not. All depends upon our past experience and the accuracy of our knowledge of the situation.

Primary Experience.—It is clear that in ideational learning and in the processes of thinking and reasoning, all depends upon primary experience. Ideas, the elements of knowledge, are derived from perceptual experience. We must therefore take pains to see that children have wide experience, that the facts of experience are corrctly interpreted. The child must have a first-hand experience with nature—with all the forces of nature and with all the objects of nature—with animals and plants, and with machinery. It must learn their names, and their uses or functions. It learns by seeing, hearing, touching, tasting, smelling, etc. In getting knowledge of things, nothing can fully take the place of direct experience. No description of the taste of sugar could ever give us a clear notion of the taste of it if we had never tasted it. And if we have tasted it, no description is necessary. No description of a cow could give us a clear notion of one. All of our knowledge must be built upon actual sensory experience. If a person lacks some sense, as sight, from birth, no description can make clear to him what experience is like in the field of the sense that is lacking. The basis of all knowledge must come through the senses. Throughout all the years of a child's life, it is getting this knowledge; it is learning the world in all the world's manifold aspects. Day after day, and year after year, the individual is having new experiences, is learning new aspects of the world. The early life of the child must be economised, useless knowledge eliminated

and economical methods of learning used, so as to give plenty of time for mastery of the material world in all its various phases.

The Organization of Experience.—Since we get experience through the senses, the getting of experience is determined by the circumstances of life, by the place where we live and the time when we live. The boy on the mountain has mountain experience; the boy on the plain has plain experience. Boys that lived at a certain time and were at a certain place, witnessed the Battle of Gettysburg, others saw Lincoln, others saw Washington, others witnessed the San Francisco earthquake. The organisation of experience, however, is independent in some measure, of the original order of experience. We get experience as the chances of life determine. In accordance with the law of association, things are bound together which have been experienced together. But things which we have experienced together may have for us no useful connection. Chance may determine that I see a rattlesnake and hear a hoot owl at the same time, but this connection of the two may have no use for me. We can organise our experience by thinking it over in helpful relations. The important idea for me to have when I see a rattler, is not of an owl but that the snake may bite me and that its bite is poisonous. Out of the raw material of the day's experience, we reconstruct a useful world, the world that concerns us. The objective world is not lawless. The order in it determines the order of our ideas. But certain relations in the world are more important to us than others. We therefore *reorganise* the world by thinking over our experience in the relations that are important to us. The causal relation is usually most

important to us. The causal sequences exist in nature, and it is best for us to fix them in memory by repeated thinking of the ideas in the causal sequence. But many things that happen together have no causal relation, as my seeing the snake and hearing the owl. Repeated experience on our part is necessary to enable us to distinguish true causality from mere accidental concomitance. Older people, as our parents and teachers who have had more experience, can be of great service to us in the organisation of our experience. They can point out to us the important relationships and aid us in establishing them in the sequence of our ideas through repetition.

Getting Knowledge.—To live in this world we must be able to control it. To control it, we must have knowledge of it. Since some aspects of the world are more important to us than others, some knowledge is more important than other knowledge. One function of the school is to help the child to get and organise useful knowledge, such as knowledge of the mechanical, physical and chemical aspects of the world; knowledge about animals and plants, knowledge about the human body—its organs and their functions, how to keep healthy, how to keep strong,—civic and social knowledge. Just what this knowledge should be in detail we shall not here enquire. We want simply to get a general view of it. The child must learn certain aspects of the world to enable him to control it and to direct his life in it. The question we wish to raise here is *how we can economically get this knowledge*.

But first let us recall fully the nature of knowledge. Knowledge consists in the names of things coupled to the ideas of the things and the functions or uses of the

things coupled to the names. These we must know. From infancy the process of getting this knowledge goes on. The child learns how to move about in its little world, learns what will hurt it and what will not, what it can manipulate and what, not. Year after year more and more knowledge is added until at maturity we have usable knowledge about most material things. Our method of getting all this knowledge is through perception. There is no other way. We see the objects of the world, touch them, taste them, smell them, hear them. We note their actions. We experiment with them and thereby learn their characteristics and their ways of reacting. We wish, for example, to learn the various factors that determine the germination of seeds. We therefore try to germinate seeds under all possible conditions, without air, without moisture, without heat, and with various combinations of these factors and with various degrees of these three factors. As a result of our experiment, we learn the factors that are necessary for germination. All our basic knowledge of the world must be got either by careful observation of phenomena as we meet them or from the results of carefully planned experiments. The child must be taught not only to be a close observer, but a critical observer.

Analysis of Experience.—The process of getting knowledge and of organising knowledge is constantly one of analysis. In the first place our notion of qualities and all abstract characteristics comes through a process of analysis, and analysis is possible through experiencing things in a great variety of relationships. We get the idea of redness by experiencing different things of different sizes and shapes having this char-

acteristic. We get the notion of triangularity, of squareness, of roundness, etc., in a similar way. From a variety of experiences our general notions crystallize out. The world at first is largely unitary. Every day of our life, it falls apart into its separate parts, and the parts into their separate characteristics. The relationships among the parts grow ever more subtle and intricate. As we grow older, bonds are possible between ideas that were not possible before because the ideas did not and could not exist for us before.

Meaning.—The most important thing about an idea is its meaning. The meaning of an idea is another idea closely associated with it. Since an idea may have many such associations, it may have many meanings. The most important meaning of an idea is the use to which the thing represented by it may be put. Of all the things that the idea of an object may bring to our mind, what most concerns us is what we can do with the thing, how we can make it serve our purposes, how it is likely to affect us, whether it will harm us or do us good.

Ice is cold, hard, slick. It may be used to keep our food cool in the refrigerator, to cool our drinking water, for making ice cream, etc. A pencil is a thing made of wood, with lead inside, but more important, it is a thing with which I can write a letter. An ax is a thing used for chopping, a saw for sawing, a fork for conveying food to the mouth. Shakespeare was a dramatist; Longfellow, a poet. Sympathy is feeling *with* another. The meaning of an idea is, then, another idea that represents some characteristic, some relation, some use. Most of our knewledge is knowledge of meanings. Most of our progress in knowledge consists in learning

new meanings. The development or growth of the meanings of the same thing are almost unlimited. A flower to a child is not the same thing that it is to a man or woman, and far from the same thing that it is to a technical botanist. To the child it may be a pretty thing that has an agreeable odor; to the botanist, it may still be this and in addition a means of developing seeds for propagation. A stone may be to a boy merely a thing to be thrown at a dog, to the geologist it tells a long story about a most interesting past. Long and intimate experience with objects reveals meanings before undreamed of, subtle relationships, resemblances before unnoticed. How different from ours is the botanist's notion of a plant! What different aspects does the world take on to the mathematician, the physicist, the chemist, the geologist, the zoologist, the psychologist! How different is the world of the farmer from that of the banker or merchant!

As the years go by we severally build up for ourselves our own particular kind of world with meanings suitable to our needs and uses. To the doctor it becomes a world of disease; to the preacher, a world of sin; to the physicist, it is a world of forces. At bottom, it is all the same world, but we have seized upon different aspects of it and thereby narrowed our interest in it, and circumscribed our knowledge of it. This course is necessary, because since we of necessity must deal with and manipulate different aspects of the world, we must know these aspects with more fullness than we know other aspects that do not directly concern us. Trouble comes when we forget that our world is only a partial world and not the whole world. I may be interested only in the top of things; others are inter-

ested in the bottom. I may be interested only in the outside of things; others are interested in the inside. It takes both top and bottom, both outside and inside to make the whole.

The school should help the child to organise the world with reference to useful meanings. The child should always be asking the question, what does this thing mean? What is its true significance? What caused it? What will it cause? What is its relation to other things? In history, for example, what are the causes? What results follow? What are the underlying movements? What does Socrates mean? What, Napoleon? What, Lincoln? What means the Renaissance? What, the French Revolution? In literature, what means Oedipus Tyrrannuus? Macbeth? King Lear? Othello? Romola? The Scarlet Letter?

A defect in our acquiring knowledge and meanings is that often we get the knowledge in an abstract, isolated sort of way apart from the real situations of life. As a result, we do not really have knowledge of an actual world, we do not have clear comprehension, and when situations arise when the knowledge would be available, the right idea does not readily come to us because the knowledge was not learned in connection with that particular kind of situation, consequently the situation often fails to arouse the right association.

Reasoning Specific.—Is reasoning capacity general or is it specific? Can we speak of a person being a good reasoner in general or do we have to say he is a good reasoner in such and such fields and a poor reasoner in other fields? These questions can be answered in the light of the facts already given. Since reasoning depends upon experience, one can not reason in fields

where he has had no experience. One may have knowledge ever so extensive in other fields, but if he have no botanical knowledge he can not reason in the field of botany. There are some aspects of reasoning, however, that are in a measure general. There are certain criteria for the testing of truth that are of general validity. The assumption that a phenomenon always has a cause is one that can be made in all fields. The practice of being cautious, of waiting until all the facts are examined is of general validity, as is also that of putting a conclusion to the practical test of experiment. Training in reasoning must, therefore, be rather specific. If one wishes to be a great reasoner in the field of physics, he must get a large experience in that field. He must learn all the laws and principles and be familiar with the methods of the science. One can be trained in reasoning, (1) in getting a wide experience in the field wherein he is to reason, (2) in the matter of being cautious and waiting to examine all the facts, and (3) in putting the conclusion to the practical test of experiment or experience.

Measuring Reasoning Capacity.—How well one can reason, or how well one can learn to reason depends upon hereditary factors as well as upon experience. People of the same experience have different capacity to reason. Some people, by reason of inheritance, seem able to know what is significant, what relations are important, while other people have little ability to see relative values, and it seems they can never learn to do it. Our ability to reason, then, has certain hereditary limitations. Since reasoning depends so largely upon experience and since few people have had anything like the same experience, its measurement is difficult,

and can be accomplished only approximately. How well one has established certain logical relationships, is to a considerable extent indicative of one's ability to reason. The measurement of these verbal relationships is then, in a measure, a measurement of reasoning capacity. Such is accomplished by the opposites test, the genus-species test, the part-whole test, and other similar tests, also by the analogies test. Certain tests, as those of Bonser, have been specifically devised to test reasoning capacity. Specific reasoning tests are likely to have the defect that they demand specific experience and training; for example, problems in arithmetic are good measures of reasoning capacity only if those measured have had equal opportunity to learn the principles of arithmetic.

Verbatim Learning.—Learning the actual words of a selection is a task not often required of people generally, but in all grades of school some verbatim learning is necessary. Experiments have shown that learning by small bits, a line at a time or a few lines at a time, is not the most economical way. There is a saving of time in the learning of either prose or verse by working on a large segment at a time, reading this large segment clear through from beginning to end till the part is learned. In the experimental work it appeared that there is a saving in the *whole* method on selections up to one 240 lines in length, as compared to learning the same selections by small bits or the *part* method. No experimenter has used selections longer than 240 lines.

Each of the two methods, however, has its advantages and disadvantages. If a selection is divided into parts and each of the parts learned, and the time for

learning the separate parts added, it is found usually to be less than the time for learning the selection by the whole method. But after the selection is learned in parts, it takes more time to cement the parts together, so that the total is greater than the time required by the *whole* method. The weakness of the whole method is that it is difficult to maintain a high degree of attention throughout a long selection. Furthermore, there is much over learning. Some parts are learned long before the others. In spite of both of these factors, the whole method proved more economical. A combination of the two methods in a way to utilise the good points of each is probably to be recommended in practice, such a combination, for example, as learning a segment of several lines, then another; occasionally going over it from the beginning as far as learned, and also occasionally going through the entire selection.

The experimental work on which the preceding statements are based, was done with meaningful material in prose and verse. Pechstein has recently reported that with nonsense material, the part method is the best, and gets favorable results by a combination of the two methods.

How to Study.—When a student sits down to study a lesson, how should he proceed? Of course, the answer depends somewhat on the kind of lesson, whether in chemistry, history, or mathematics, for example. Generally, a lesson contains but a few facts or principles. The student should first read through the assignment as a whole to get the general drift of the argument or description, then he should go back and pick out the

essentials. As a rule, one should underline in the text the crucial, fundamental statements, so as to make it easy to turn through the pages and get the fundamental thoughts. The student should make sure of what the author says, of the meaning and of its significance. He should always put the question: What does this mean? Especially, What does it mean to me? The author should be translated into the understanding and experience of the student. In reading a book, it should always be our task to find out the author's meaning. Certainly we should not attempt to criticise before we know what the author means. The student should early learn to discriminate between fact and theory or opinion, and should always note carefully whether an author is giving facts, or the author's opinions, or the opinions of some one else. Unfortunately many people go through life without learning to discriminate between a fact and an opinion.

EXPERIMENTS AND EXERCISES.

1. Association. The object of this experiment is to make a study of the factors that determine the connection of ideas. In a class experiment nothing beyond illustration should be attempted. The free association experiment will serve well enough for this purpose. The instructor should prepare a list of words, then pronounce them one at a time to the class. When a word is pronounced the students are to write down the first word that comes to their minds. Let the students determine the factors operative in the case of each word, considering recency, primacy, frequency, intensity, mental set and emotional factors. The experiment should make it clear that there is nothing in the nature

of ideas as such that bind them together, that the way in which they become bound together is a matter of experience.

2. Reasoning. The object of this experiment is to show that reasoning depends primarily upon experience and the ability to recall the experience when it is needed. The instructor should prepare a number of problems and questions for solution and answer. The following will serve as examples: If a rope were stretched entirely around the earth at the equator and then lengthened six feet, how much space would there be between the earth and rope, supposing the distance to be made equal all around? Suppose three inch-circles are tangent, each to the other two, what is the area of the space between the circles? Suppose a bar of iron is riveted to a similar bar of copper and the combined bar is then heated in the middle, which way will it bend? If a metal ball four inches in diameter weigh 50 pounds, how large must a ball of the same metal be to weigh 100 pounds? If a cube of ice weighing ten pounds melts in an hour, how long will be required for a twenty-pound cube to melt, the temperature of the surrounding air being the same?

Give the above and similar problems to the students and let each report on the reasoning processes that follow. When a problem can not be solved, determine whether it is because of lack of experience or inability to recall the experience.

3. "Knowledge consists in the association of the name of a thing with the idea of the thing, or the function or some characteristic of a thing with the name or idea of the thing." Let the student verify this statement by an examination of various kinds of knowledge.

4. Give several illustrations showing the difference between primary and secondary experience.

5. Make a study of meaning by getting the responses of students to various characters in literature and history and to objects in nature. Put the questions as follows: Who was Caesar? Pericles? Shakespeare? Hamlet? Othello? Antigone? What is sulphur? Iron? Platinum? Heliotrope? Water? Oxygen?

The experiment should show that the same person or thing may have different meanings to different people.

Interesting facts are learned by reading short bits of literature to the class and having each student give his interpretation.

6. "All knowledge of function and characteristics is analytic." Let the student verify this statement by an examination of many different kinds of knowledge.

7. The instructor can measure the reasoning capacity of the members of the class by giving several controlled association tests, several completion tests, and by giving specific problems. The elements needed in the solution of the problems must have been within the experience of the students. In exercise 2 above, the problems may very well go outside the experience of the students, but in a study of reasoning ability, the problems must be within the experience of the students. The best reasoner is he who makes the best use of his experience.

8. In Chapter VI, the students are asked to apply the facts of the chapter to the habit-formation aspects of the public school curriculum. Make a similar application of the facts of this chapter to the ideational learning involved in the public school branches. Show, for example, that in history, the child is learning the names

of people and places and the causes and consequences of events. The students should carefully work out the knowledge aspects of each school study.

REFERENCES.

Brown, W., *Practice in associating color names with colors*, P. R., XXII, 1915, 45.

Practicing in associating number names with number symbols, P. R., XXII, 1915, 77.

Dewey, J., *How we think*, 1910.

Hall, G. S., *Some psychological aspects of language teaching*, Ped. Sem., XXI, 1914, 256.

Judd, C. H., *The psychology of high school subjects*, 1915, Ch. XVII on Generalised experience.

Lakenan, M. E., *The whole and part methods of memorising poetry and prose*, J. E. P., IV, 1913, 189.

Otis, A. S., *Do we think in words?* P. R., XXVII, 1920, 399.

Pechstein, L. A., *Whole vs. part methods in learning nonsensical syllables*, J. E. P., IX, 1918, 381.

Alleged elements of waste in learning a motor problem by the "part" method, J. E. P., VIII, 1917, 303.

Pyle, W. H. and Snyder, J. C., *The most economical unit for committing to memory*, J. E. P., II, 911, 133.

Thorndike, E. L., *Repetition vs. recall in memorising vocabularies*, J. E. P., V, 1914.

CHAPTER VII.

THE RETENTION OF EXPERIENCE.

Learning and Memory.—Learning would be impossible without memory. To learn means to become changed, different from what we were before. If the difference is not retained, at least for some length of time, then we have not learned. Learning and memory each involves the other. To learn means that we must have memory; to remember means we must have learned.

Memory—the retention of experience—is one of the most remarkable facts of human life. Any bit of experience leaves us different from what we were before. Every new habit, every repetition of an old habit, every bit of new knowledge, makes us a somewhat different person. This is because we are the sum of our experiences and tendencies; because we are the result of our accumulated experience.

It is memory alone that puts meaning into life. A merely perceptual life would be meaningless. Every perception arouses ideas which have resulted from past experience, and which give the perception meaning. The importance of memory, the part it plays in life, is at once evident when one tries to imagine what life would be without it. If every new experience were to us as if it were our first, if it called forth no echoes of a past, it would not really be experience. Experience must have a longitudinal dimension as well as a transverse one. It consists in a union of past and present.

Learning and memory are really different aspects of the same thing. To learn means to become different. To remember means to retain the difference. Much of the experimental work in memory might well be called studies of learning, and many learning experiments might well be called studies in memory. It is all a matter of emphasis. In this chapter we are to consider those facts which bear more especially on the retention of experience. We shall use the term memory in a general sense as synonymons with the expression *retention of experience.*

Memory and Age.—Ability to retain experience, as far as it can be measured by experimental means, improves with age from the earliest time in childhood when such measurements are possible, up to maturity or near maturity. Of course, retention is different with different aspects of experience, but age brings improvement in all aspects. If we show children a number of objects, a number of pictures of objects, a number of names of objects, or a number of abstract words, and then determine later how well the experience is retained, we find that it is better with each succeeding year till near maturity. If we read a story to children, and later determine how well the story is retained, we find retention better up to near maturity. There seems little increase in ability to retain experience after about thirteen years of age. In fact experiments often show a falling off of ability to reproduce stories during the high school age. It is quite likely that this apparent decrease in memory capacity is due to a certain attitude of the subjects and not to any decrease in retentive capacity. In the earlier years, children reproduce, parrot-like, stories read to them, without discrimination.

Older children reproduce only the salient facts, through habit omitting details. This attitude results in a lower score. A careful study of all the experimental work in this field leads one to the conclusion that retentivity, as far as it can be measured by experiments, improves considerably to about the age of adolescence, then more slowly to the age of physical maturity. There is no undoubted evidence of a decline of retentivity before middle age. Improvement in retention due to age is shown in tables 5, 6, and 7:

TABLE 5.

THE RELATION OF MEMORY TO AGE AND SEX (PYLE).
CONCRETE ROTE MEMORY—CITY CHILDREN.

	Boys.		Girls.	
Age.	Number Cases.	Average.	Number Cases.	Average.
8	176	17.46	172	18.59
9	249	19.77	297	19.76
10	348	20.82	321	20.94
11	376	22.03	330	22.81
12	346	23.30	347	24.22
13	339	24.12	358	24.69
14	266	24.83	304	24.97
15	277	25.40	247	25.78
16	155	25.66	183	26.96
17	73	26.72	121	27.28
18	46	27.15	64	27.52

TABLE 6.

ABSTRACT ROTE MEMORY—CITY CHILDREN.

	Boys.		Girls.	
Age.	Number Cases.	Average.	Number Cases.	Average.
8	174	15.70	172	17.19
9	255	18.01	297	18.49
10	349	19.25	319	19.66
11	375	20.02	330	21.05
12	348	21.22	350	22.56
13	339	21.14	359	23.35
14	267	23.16	303	23.66
15	228	23.87	248	24.64
16	155	24.13	181	25.71
17	77	25.74	121	25.88
18	46	26.44	64	27.13

TABLE 7.

THE RELATION OF MEMORY TO AGE AND SEX (PYLE).
MATERIAL USED, THE MARBLE STATUE.
CITY CHILDREN.

Age.	Boys. Number Cases.	Boys. Average.	Girls. Number Cases.	Girls. Average.
8	102	24.3	89	28.5
9	148	28.7	158	21.0
10	142	30.0	138	33.5
11	149	32.9	156	36.4
12	156	35.1	191	38.1
13	163	33.8	164	38.5
14	129	36.1	146	39.0
15	89	36.5	99	39.1
16	60	34.4	94	37.3
17	45	34.6	81	36.6
18	65	38.3	86	40.1
Adults	65	38.3	86	40.0

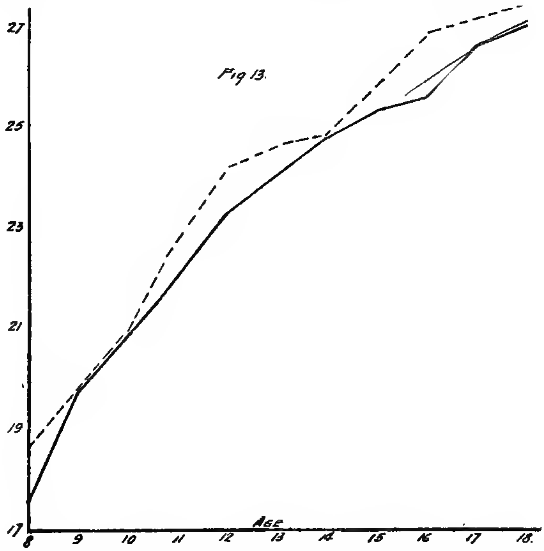

FIGURE 13. ROTE MEMORY GRAPHS, somewhat smoothed, ages 8 to 18, broken line girls, solid line boys.

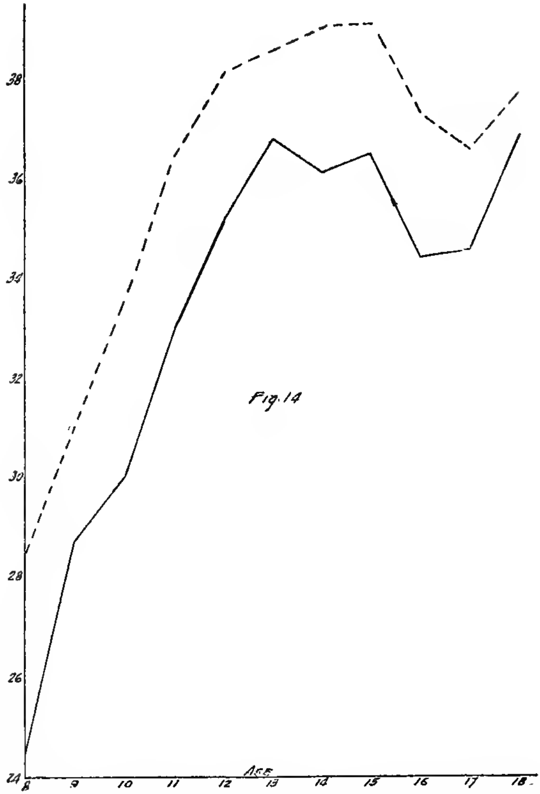

FIGURE 14. LOGICAL MEMORY: results from the Marble Statue test. Broken line, girls; solid line, boys.

Memory and Sex.—The fact that there is an improvement in the various aspects of memory with age, shows that retention is a function of development. Since girls mature faster than boys we should expect their retentivity to be better. Experiment reveals this to be the case. In tables 5, 6 and 7 the relative memory effi-

ciency of boys and girls is shown for the different ages from eight to eighteen. The comparison is shown graphically in figures 13 and 14. It can be seen from the tables that girls are better in rote memory at every age except nine, in concrete rote memory. Here the boys excel by a hundredth of a word. While the girls, with this one exception, are uniformly better, the difference is very small. The average yearly improvement of boys from nine to eighteen is 3.94%, while that of girls is 4.03%. The large gain shown for the boys in concrete rote memory from eight to nine is doubtless spurious, due to the inaccuracy of measuring eight-year-old boys.

In logical memory, as determined by using *The Marble Statue* test, the girls are better at every age from eight to eighteen. And university women are better than university men. It must be said, however, that in tests of logical memory, the results depend upon the kind of material used. This may be true of rote memory as well. In *The Farmer's Son* test used by the author, boys are better from eleven to fifteen. The author used three tests of logical memory, one called *Willie's Dog* in the lower grades, one called *The Farmer's Son* in the upper grades, and one called *Costly Temper* in the high school. There are records for age 13 in all three tests. In the *Willie's Dog* and *Costly Temper* tests girls are better at age 13, while in the *Farmer's Son* test, at the same age, boys are better. At age 13, the average score for boys in the three tests is 38.46, and for girls, 39.57. There are so many factors effective in learning, which have their influence on retention, that it is difficult for us to compare the retention of girls and boys. We can say that in any given

test one sex is better than the other, but whether it is better because of better retentive capacity or because of difference in attitude, attention, interest, or familiarity of the material, it is difficult to say. However, in the extensive experimental work in memory, the superiority of girls over boys is so general that we are warranted in concluding that they have a better retentive capacity.

Some experimenters have reported boys as having better retention in certain fields of memory. Mulhall, for example, reports boys as having better memory for form, and cites Chamberlain as having found no sex difference. But both these experimenters make their comparisons by grade and not by age. Now, in the same grade the boys average older than the girls. An adequate sex comparison should be made by *age*, not by *grade*. Several writers have stated conclusions about sex differences, with this same error entering into their calculations. However, even if we are careful to make sex comparisons by age and not by grade, we may expect to find boys superior if they are favored by either material or interest, i. e., if the experience of boys makes a certain material used in the test more suitable to them than to girls. It seems clear, however, as stated above, that if we rule out the influences due to differences in experience and interest, the retention of girls is better than that of boys.

Girls have better retention than boys, but do women excel men? Gates, basing his conclusion on an examination in psychology, finds women better than men in both immediate and delayed recall. It is possible that the women had spent more time in study, and remembered better because they had learned better. In the

author's experiments, men and women were on an equality as far as opportunity of learning was concerned, for in both rote and logical memory, the material was presented to both men and women in the same manner, at the same time. In concrete rote memory 38 university men make a score of 28.5, and 61 university women make a score of 28.6. With abstract words, 40 men make ascore of 28.4, and 61 women make a score of 27.9. There is but little difference, the women excelling by one-tenth of a word in the test with concrete words and the men excelling by five-tenths of a word in abstract rote memory.

In logical memory, with *The Marble Statue* as material, 65 university men make a score of 38.3, and 86 university women make a score of 40.1. The women have a superiority of 1.8 words, or 4.7%. There is the possibility that this story makes a stronger appeal to women than it does to men. The difference between boys and girls with this same test is nearly twice as great. The average score of boys from 8 to 18 is 33.3, while the average score for girls is 35.9, a difference of 2.9 words, or 8.7%. The comparison of boys with girls is based on tests of 1215 boys and 1364 girls.

Briefly, in summary: The retention of girls is better than that of boys because of their more rapid development. At maturity, there is no clearly demonstrated sex difference not due to experience, training or attitude.

Effect of Practice.—Can we improve memory by practice? We are constantly having experience, and consequently have constant practice in retention. We have as much practice in retention as we do in sensation. Sensation does not need, in ordinary cases, spe-

cial exercise to develop it. Will special exercise in memorising permanently improve the retentive capacity of the brain? James, some thirty years ago, answered this question as follows: "All improvement of the memory lies in the line of elaborating the associates of each of the several things to be remembered. *No amount of culture would seem capable of modifying a man's general retentivenes.* This is a physiological quality, given once for all with his organization, and which he can never hope to change".* The great amount of experimental work in memory gives us no reason for modifying James' statement. The experiments do prove beyond doubt, however, that we can greatly improve our ability to memorise. In all kinds of material at least some improvement comes through practice, from the learning of nonsense syllables on the one hand to the learning of the logical material of a book on the other. But that this improvement is in any sense due to an improvement of the retentivity of the brain it would be difficult to prove.

Winch using consonants as material, presenting them visually and later in another experiment, auditorially, found an improvement in ability to memorise, due to practice. Bolton using digits as material, also found improvement from practice. Müller and Schumann found an improvement in ability to memorise nonsense syllables. The author found a large improvement in ability to learn the substance of a text book in sociology. The experiment was conducted as follows: About a page of material was read to the subject, who then repeated all the ideas he could recall. The selection was then read again, and the ideas reported. This pro-

*James, Principles of psychology, Vol. I, p. 663.

cedure was continued till the subject could report all the ideas of the selection. After three months of practice, the subject could memorise in fifteen minutes an amount of material that required an hour at the beginning of the experiment. The improvement doubtless depended upon an improvement in methods of getting and organising the facts, and in an increased familiarity with the matter discussed in the book used as material. Improvement in memorising comes with so little practice and in so short a time that it is absurd to believe that the retentivity of the brain could be affected.

However, we must not forget that we can tremendously improve our ability to fix our experience so that it will be retained. We can become immensely better at remembering not because we have changed the brain so that it retains simple impressions better than before; through better attention, better and more repetition, better and more associations, we so organise our experience that it is much more lasting than if got with poorer methods. Poor retention is usually due to poor attention, lack of repetition, poor organisation. We can improve retention by improving these factors. The possibility of improvement in memorising is much greater in logical material, connected ideas, than it is with discrete material, as letters, words, nonsense material, because of the greater possibility of organisation on the basis of meaning.

Relation of Learning to Retention. — Our question here simply stated is, whether facility in learning and facility in retention are positively or negatively related. Do quick learners retain well and poor learners retain poorly, or is the reverse the truth? In general, the

results of the experiments are in accord. The work of Müller and Schumann, Ogden, Henderson, Norsworthy, Lyon and the author leads to one conclusion: in general, the fast learner is also good in retention. This is especially true with logical material, such as prose and poetry. The experimenters used all kinds of material, nonsense syllables, words, digits, and selections in prose and verse. We give some typical results.

In the author's experiments, each subject learned the ideas in 21 separate segments of prose material. The segments were of equal length, each containing 40 ideas. The procedure was to read the matter to the subject till all the ideas could be reproduced. The number of readings was taken as the score. Twenty-four hours later a written reproduction was required, and the number of ideas correctly reproduced was taken as the score. The results were as follows:

TABLE 8.

Subjects.	Number of Repetitions.	Average Deviation.	Ideas Retained.	Average Deviation
C	4.7	2.24	37.5	2.0
F	2.9	0.78	38.5	1.7
K	5.2	1.40	34.2	4.6
J	3.6	1.90	36.7	3.2

The quickest learner is F, the slowest is K. Subject F requires only 55.7% as many repetitions as K, but retains 11% more ideas. It will be noticed that there is less difference in retention as measured by the absolute amount that could be reproduced than there is in learning. There is general agreement among all experimenters on this point.

Norsworthy found that the students who learned the greatest number of words in a German-English vocabulary, in a given time, retained the largest percentage of what had been learned. The most extensive work on

this problem was done by Lyon. He used three different methods of testing retention. (1) The first was by the absolute amount retained. (2) The second was by the amount reproduced after hearing the material read once again. (3) The third was by the amount of time taken to relearn the material. Using method 1 as the criterion of retention, we find the fast learners are the best in retention in all forms of material used, poetry, prose, nonsense syllables, words, and digits. Using method 2 as our criterion, we find the fast learners the best in retention except in the case of digits. But by using method 3 as our test of retention, we find the fast learners the best in retention in the case of logical material, prose and poetry, only. By all the tests of retention, the fast learners show up the poorest in retention in the case of the digits. The greatest variability in learning time was shown in the case of digits. Commenting on his results, Lyon says: "Taking all three methods into consideration, we are entitled to say that with material that is logical in character, *those who learn quickly remember the longest.* With digits, however, we find the conditions, so far as method 3 is concerned, reversed, for here it is the quick learners who seem to forget the most. One might make the inference that those who learn *slowly* remember *long*, if the material used is such as involves *motor associations*, but that they forget *quickly* if the material is logical in character." Lyon found that, as far as method 3 was concerned, nonsense syllables gave the same sort of results as prose material, and that words gave the same sort of results as digits. For this apparently strange result, Lyon has "no satisfactory explanation to offer."

An experiment performed in the author's laboratory confirms the results given above. The material used was nonsense syllables, 25 in a series. The procedure was to learn the series at one sitting, by repeating the syllables to the stroke of a metronome, then relearning them on the second and succeeding days until they could be said from memory twenty-four hours after the last learning. The number of repetitions required to learn the syllables the first time is called the learning time. The total number of repetitions at the different sittings is called the total learning time. The ratio is found by dividing the total learning time by the first learning time. As a rule, those who are quick in first learning are quick also in relearning.

TABLE 9.

NONSENSE SYLLABLES.

Subject.	Learning Time, No. Repetitions.	Total Learning Time.	Ratio.
Wi	123	150	1.2
Th	121	129	1.06
We	118	147	1.2
Sw	99	136	1.4
Sn	72	85	1.2
B	59	70	1.2
Average	96	117	1.2

Another experiment somewhat similar gives results in harmony with those given above. The author gave a logical memory test to about 2000 school children in grades three to eight. Whipple's *Marble Statue* was read to the pupils and an immediate reproduction required. One month later a second reproduction was called for. Standing in the immediate memory test was correlated with standing in the retention test taken one month later, the correlation being computed by grades. The correlations by the Pearson formula ranged from .50 to .80.

The evidence seems conclusive that quick learning and good retention are positively related. However, the relation is not simple and there are many things that must be taken into consideration. If slow learning is due not to poor learning capacity but to caution and care in learning, then slow learning will be coupled with good retention. On the other hand, if the quick learning is at the same time poor learning, it will be coupled with poor retention. The factors that make a person a good learner are the factors that will make him good at retention, a high degree of attention and concentration, quick and accurate apprehension, quick grasp of meaning and significance, organisation of material through schemes of meaning and association. The reason that a quick learner often seems to remember poorly is because he is content with *poor* learning, and especially because he does not take advantage of the value that comes from repetition. In comparing the retention of different individuals we should always take into consideration the quality and method of learning. It is worth noting that in Lyon's extensive experiments, he found not a single case of a consistently good learner who was consistently poor at retention. There is little doubt that Lyon would have found still stronger evidence of the positive relationship of learning and remembering if he had used a different criterion of learning. Some of his subjects doubtless had the material better learned than others.

Memory Material.—Memory of objects or pictures of objects serially presented is better than memory for the names of objects either seen or heard. Typical results are those of Calkins shown in the following table. The delayed recall is for results three (?) days after the first presentation.

TABLE 10.

	Words Heard.	Words Seen.	Pictures of Objects.
Immediate	84.2	89.8	93.5
Delayed	34.9	48.2	74.5
Ratios Imme.	1	1.066	1.110
Ratios Del.	1	1.208	2.135

It will be seen that the pictures of objects are remembered much better than the names of objects either seen or heard, and that in delayed memory more than twice as many pictures of objects are recalled than names of objects heard. Patterson compared memory for objects seen with memory for words seen and words heard. The results for immediate memory were: words heard, 6.85; words seen, 6.92; objects seen, 8.28. The ratio of objects seen to words heard is 1.209 to 1. By comparison with the table above it is seen that objects are remembered somewhat better than pictures of objects.

The educational inferences to be made from these facts are obvious. Visual illustrations by means of drawings or pictures will be helpful, and demonstrations by means of the actual objects will be of the highest value.

As for other types of material: digits are remembered better than consonants; meaningful words better than meaningless words; related words better than nonrelated words; material that submits itself to grouping better than that which does not; lists of concrete words better than lists of abstract words. In the author's study of the rote memories of 2654 boys and 2744 girls, it was found that the boys remembered 7.3% more concrete words than abstract words, while the girls remembered 5.7% more.

Manner of Presentation.—The effect on memory of the form and manner of presenting the material for

learning has not been determined beyond doubt. We shall not, therefore, go into a detailed discussion of the numerous experiments. A very general statement will suffice. On the one hand we find Meumann, Münsterberg and Bigham, Pohlmann, Smedley, and others claiming on the basis of their experiments that visual presentation is better in the case of children, especially with meaningless material. On the other hand, Kemsies, Hawkins, Von Sybyl, and Henmon find auditory presentation better.

There are evidently many factors entering into the problem, particularly the kind of material and the age of the subjects, as well as the habits and training of the subjects, possibly also their ideational type. For example, Pohlmann and others find auditory presentation best for significant material, and visual best for meaningless material. Henmon found the auditory presentation best for nouns, nonsense syllables, and numbers. But his subjects were six adults. He did not experiment with children.

Several experimenters find that memory is better if the material is presented to both vision and audition. Others find little or no advantage by such presentation. Some have reported that if the subject is allowed to articulate the learning material in addition to hearing and seeing it, memory is better. Others report no advantage.

Unfortunately, although the question of the most favorable method of presenting material to different ages of pupils and for different kinds of material is an important one for education, it awaits the solution of a future experimenter. The solution can come only from a careful consideration and isolation of all the factors involved.

Length of Series.—What is the relation of memory to the amount learned at one time? Strong's studies of advertising showed the importance of the length of series, *i. e.*, of the number of impressions at one time. He found that if only five advertisements were shown at one time, the subject could recognise 86% of them immediately afterward, while if 150 were shown, only 47% could be recognized immediately afterward. The per cent. of correct recognitions decreased as the length of the series increased. In Strong's experiments we have evidence of the relation of retentiveness to the number of impressions; in the earlier experiments of Ebbinghaus, we have evidence of the relation of the time of memorising to the amount to be memorised. Ebbinghaus could memorise a series of seven syllables in one repetition, but a series of twelve syllables required on the average 16.6 repetitions. Series of 16, 24, and 36 syllables required respectively 30, 44 and 55 repetitions. While 12 syllables were learned in a little over 16 repetitions, a series of 24, or twice as many, required not 33 repetitions, but 44 repetitions. As the length of series is lengthened beyond one's memory span, the learning time is enormously increased at first, then more slowly. The results from the experiments of Ebbinghaus and Strong are shown in tables 11 and 12.

TABLE 11.

SHOWING THE RELATION OF THE NUMBER OF ADVERTISEMENTS SEEN TO THE NUMBER THAT COULD BE RECOGNISED IMMEDIATELY AFTERWARD. THE FIRST HORIZONTAL COLUMN SHOWS THE NUMBER OF ADVERTISEMENTS SEEN. AND THE SECOND ROW SHOWS THE PER CENT. THAT COULD BE RECOGNISED IMMEDIATELY AFTERWARD. (STRONG.)

No. seen	5	10	25	50	100	150
Per cent. recognised	86	85	78	67	63	47

TABLE 12.

SHOWING THE RELATION OF THE LENGTH OF A SERIES OF NONSENSE SYLLABLES TO THE NUMBER OF REPETITIONS REQUIRED TO LEARN THEM. THE UPPER HORIZONTAL COLUMN SHOWS THE NUMBER OF SYLLABLES IN THE SERIES AND THE LOWER COLUMN SHOWS THE NUMBER OF REPETITIONS REQUIRED TO COMMIT THEM TO MEMORY. (EBBINGHAUS.)

No. syllables	7	12	16	24	36
No. repetitions	1	16.6	30	44	55

Several other psychologists have repeated the experiments of Ebbinghaus, and have also used other material,—digits, prose, and poetry. The experimenters were Binet and Henri, Meumann, Henmon, and more recently, Lyon. In Table 13 are shown the results of some of their work in parallel columns for comparison. Lyon's results are shown in Tables 14, 15 and 16. Lyon used two methods of learning. One he calls the "continuous" method, and the other, the "once-a-day" method. In the former, all the learning was done at one sitting. In the latter, the learning was done at the rate of one reading a day. The results show the latter much the better way to learn, especially in the case of non-meaningful material.

A careful study of all the tables shows that the difficulty of learning increases when the length of the material is increased. How much does it increase? If the increasing difficulty is in proportion to the increase in length, then the number of repetitions will remain constant, and the *time* will increase as the length. This is not the case. There is a general increase in the number of repetitions, showing that the difficulty increases more than the length increases. On the other hand, the number of repetitions does not increase in proportion to the increase in length. The increase in number of repetitions is greater than the increase in length at

first and then much less when the learning is done at the rate of one reading a day. When the learning was all done at one sitting the added length increased the difficulty more than when the learning was spread out. In Table 15 it is seen that 8 syllables require two repetitions. Sixteen syllables require not four repetitions, but 23. On the other hand, 32 syllables require not 46 repetitions, but only 24.

The results in the tables show some irregularities and discrepancies due to individual differences, differences in material and in some cases to difference in method. All the results agree in showing that increasing length of material increases the difficulty of learning. They disagree as to what the law of this increase is.

The educational importance of the facts shown by these experiments is very great. From the point of view of the economy of learning and memory, the number of impressions received at one time should be few. If in a lecture, for example, too many ideas are pre-

TABLE 13.

COMPARATIVE TABLE SHOWING THE RESULTS OF SEVERAL INVESTIGATORS ON THE TIME REQUIRED TO LEARN SERIES OF SYLLABLES OF DIFFERENT LENGTHS.

MATERIAL USED—NONSENSE SYLLABLES.
METHOD—SYLLABLES ALL LEARNED AT ONE SITTING.

Number of Syllables.	Ebbinghaus.	Meumann.	Henmon.	Lyon.
8	1*	5	......	5
10	......	......	7	......
12	17	10	8	69
14	......	......	8	......
16	30	17	9	83
18	......	21	11	......
20	......	......	14	......
24	44	30	13	94
30	......	......	20	......
32	......	......	......	103
36	55	33	......	......
48	......	......	......	120
72	......	......	......	306

*Ebbinghaus used 7 syllables instead of 8.

sented to the students, the results are confusion in memory and poor retention. *At any one time, a teacher should present to his pupils only a few facts. These should be illustrated, elaborated, related, organised.*

TABLE 14 (FROM LYON).

SHOWING THE NUMBER OF READINGS REQUIRED TO MEMORISE SELECTIONS OF VARIOUS LENGTHS.

PROSE.			POETRY.		
No. of Words.	No. of Repetitions.	Time, Min.	No. of Stanzas.	No. of Repetitions.	Time, Min.
15	1	3/40	1	1	⅛
20	1	1/10	2	3	¾
25	1	⅛	4	7	3
50	9	2¼	5	8	5
100	23	9	6	12	8
200	24	24	8	11	10
400	28	56	10	18	21
800	34	136	12	16	23
1000	33	165	18	22	46
1500	40	300	21	24	60
2000	35	350	25	20	58
3000	52	780	35	24	98
4000	38	760	40	22	103
5000	65	1625	50	25	146
7000	59	2065	75	30	262
10000	84	4200	100	33	385
15000	73	5475	......	......	......

TABLE 15 (FROM LYON).

SHOWING THE RELATION OF THE LENGTH OF SERIES OF NONSENSE SYLLABLES AND OF DIGITS TO THE TIME REQUIRED TO LEARN THEM, WHEN THE LEARNING WAS DONE AT THE RATE OF ONE READING A DAY. THE LAST COLUMN GIVES THE NUMBER OF REPETITIONS AS THY WOULD BE IF THE NUMBER INCREASED IN PROPORTION TO THE NUMBER OF SYLLABLES.

No. Digits.	No. Repetitions.	No. Syllables.	No. Repetitions.	
8	1	8	2	2
12	5	12	15	3
16	14	16	23	4
24	18	24	25	6
32	25	32	24	8
48	24	48	35	12
72	35	72	43	18
104	41	104	43	26
200	51	200	56	50
400	70	300	78	75

TABLE 16. (FROM LYON.)

SHOWING THE RELATION OF THE LENGTH OF SERIES OF NONSENSE SYLLABLES AND DIGITS TO THE TIME REQUIRED TO LEARN THEM, WHEN THE LEARNING WAS DONE ALL AT ONE SITTING.

No. Digits.	Time, Min.	No. Syllables.	Time, Min.
8	1/12	8	¼
12	¼	12	6
16	2	16	9
24	5	24	16
32	10	32	28
48	18	48	43
72	24	72	138
104	56	.....	.....
200	154	.....	.....

Forgetting.—As soon as we learn we begin to forget. It is well to know the rate of this forgetting, its progress for different materials, and the laws that seem to control it. The experimental work of chief importance here is that of Ebbinghaus, Radossawljewitsch, and

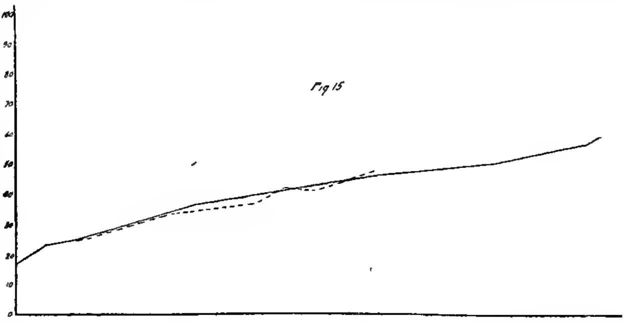

FIGURE 15. The solid line is a logarithmic curve. The broken line is a forgetting curve constructed from the actual data.

Finkenbinder. The results of these three investigators are shown in table 17. The differences in the results from the three sources are due to differences in method,—differences in method of presentation of the

material and differences in determining when learning was completed. The work of Finkenbinder was the more accurate. A study of the table and the graphs shows that forgetting, in the case of nonsense material, is very fast at first and then slower. The fourth column in the table gives the figures for a theoretical logarithmic curve, which the curve for the nonsense syllables as shown in column one approximates. Such a curve is shown in Fig. 15, also an actual curve constructed from the data in column 2.

TABLE 17.

AMOUNT FORGOTTEN AFTER LAPSE OF DIFFERENT INTERVALS OF TIME. (AFTER FINKENBINDER.)

	Finkenbinder.			Radossawljewitsch.		Ebbinghaus.
	Nonsense Syllables.			N. S.	Mean	
Interval of Time.	Av.	P. E.	10 Log.	Av.	Av.	Av
120 days	......	......	62.3	97.2	......	......
5 minutes	......	......	16.9	2.5	......	......
20 minutes	......	......	23.0	11.4	3.9	41.8
30 minutes	25.0	1.3	24.7	......	......	......
1 hour	27.2	.6	27.7	29.3	21.7	55.8
2 hours	30.6	1.8	30.7	......	......	......
4 hours	33.6	1.7	33.8	......	......	......
8 hours	34.5	1.4	36.8	52.6	41.9	64.2
12 hours	36.2	1.4	38.5	......	......	......
16 hours	37.0	.9	39.8	......	......	......
24 hours	42.2	1.8	41.5	31.1	20.3	66.2
36 hours	41.2	1.9	43.3	......	......	......
2 days	44.5	1.8	44.5	39.1	33.2	72.2
3 days	47.9	1.7	46.3	......	43.5	......
4 days	......	......	47.6	......	45.5	......
5 days	......	......	48.6	......	43.5	......
6 days	......	......	49.3	50.7	57.6	74.6
7 days	......	......	50.0	......	50.0	......
14 days	......	......	53.0	59.0	70.0	......
21 days	......	......	54.8	62.2	52.4	......
30 days	......	......	56.3	79.8	76.1	78.9

Bean finds five factors which contribute to an explanation of the curve of forgetting.

(1) The rate of forgetting depends on the degree to which the material had been learned before the commencement of the period of forgetting. Overlearning makes forgetting slower.

(2) The rate of forgetting depends on the *method* of learning, i. e., on such matters as the concentration and distribution of practice. Distributing learning makes forgetting slower; concentrating learning makes forgetting faster.

(3) The rate of forgetting varies with the kind of performance in habit-formation, or the kind of material in ideational learning. Significant material, for example, is forgotten more slowly than meaningless material.

(4) The rate of forgetting varies with the method by which forgetting is measured. Bean thinks forgetting is faster if measured by the reproduction method, slower if measured by the relearning method.

(5) The rate of forgetting varies with different individuals.

To these factors should be added two others. First, the rate of forgetting varies with the amount learned at one time. If a small amount is learned, forgetting is relatively rapid at first. If a large amount is learned at once, forgetting is slower at first. This fact is a corollary of (2) above, for learning a large amount makes necessary spreading out learning. If twenty-four syllables are learned at one time, the learning is spread out over much more time than if only twelve syllables are learned. Second, fast learners, with other factors equal, are slow forgetters.

The main facts of the psychology of forgetting. briefly summarised, are as follows: If the material learned is new material, the ratio of what is retained

to what is forgotten varies inversely as the logarithm of the time. This is the conclusion to which Ebbinghaus came, and nothing that has since been discovered gives any cause to modify the statement. The rate of forgetting is different with different materials, different methods, and for different individuals, but it is always very fast at first, then slower and slower. In Ebbinghaus' experiments, more than one-third of the syllables were forgotten in the first twenty minutes; more than one-half in one hour; nearly two-thirds in nine hours; more than two-thirds in 24 hours. In the experiments of Radossawljewitsch with meaningful material, one-third was forgotten within two days, while one-third of meaningless material was forgotten in one day; one-half of meaningful material was forgotten in 7 days, while one-half of meaningless material was forgotten in 6 days. In 30 days three-fourths of the meaningful material was forgotten and four-fifths of the meaningless material.

Meaningful material is not forgotten as quickly as meaningless material, because it is not new material, and the learning of it has been going on perhaps for years, in some cases, all our lives. The learning of meaningful material means merely the re-arrangement of what we already know. If we undertake to commit to memory Evangeline, we read: "This is the forest primeval, the murmuring pines and the hemlocks," etc. Neither the words nor the thought is new. This fact makes the learning of meaningful material a wholly different matter from the learning of meaningless material.

Retention Over Long Periods.—The longest interval shown in Table 17 is 120 days. We have now to enquire

concerning the effect on retention of a much longer interval. We shall consider only the work of Book and Swift. The former tested the retention of typewriting skill after a lapse of about six months and of a year and six months. The original practice had cov-

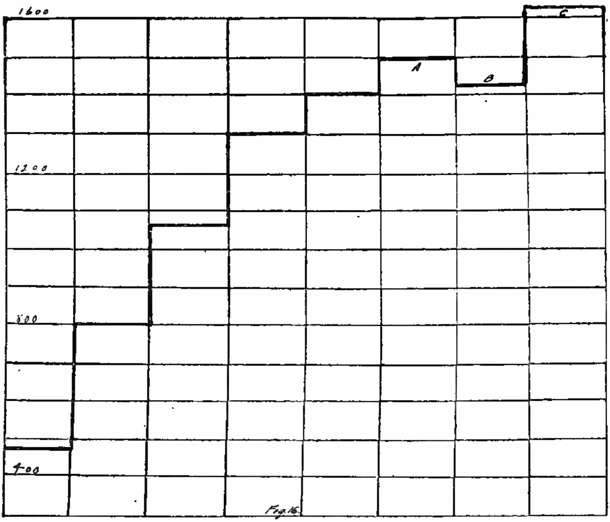

FIGURE 16. TYPEWRITING GRAPH FROM BOOK. The graph from the left up to A shows the results of the 60 days practice. At A is shown the result of the final ten-minute practices for the last ten days of the experiment. B shows the efficiency reached by ten days of practice six months later. C shows the efficiency reached by ten days of practice a year and six months later.

ered a period of 60 days, an hour a day. Practice ceased on January 16, 1906. On June 1, a test began and continued ten minutes a day for ten days. On June 1, 1907, a second test of ten minutes a day for ten days was begun. The results are shown in Table 18 and also in Fig. 16.

TABLE 18.

RETENTION OF TYPEWRITING SKILL (BOOK).

Last regular parctice, Jan. 7-16, 1906........	1503	1509	1404	1572	1494	1436	1501	1455	1508	1698	1508
1st memory test, June 1-10, 1906	1365	1421	1421	1433	1529	1443	1523	1504	1313	1472	1443
2nd memory test, June 1-10, 1907	1390	1344	1345	1537	1681	1694	1634	1845	1761	1850	1611

In the regular practice there had been 50 minutes of practice and a ten-minute test each day. In Fig. 16 are shown the learning curves for these ten-minute tests for the last ten days of practice, also for the ten ten-minute tests made on ten successive days about six months, and a year and six months later. The striking thing about this experiment is the quickness with which the skill was regained. Although nearly a year and a half had passed since the regular practice ceased, in ten minutes daily practice for ten days the skill was regained, and an average of 1611 words was made as against an average of 1508 made on the last ten days of practice.

Swift's experiments were with ball-tossing. The practice was finished on Dec. 11, 1902. Memory tests were made in 1903 and 1904, and again Dec. 28, 1908, six years and 17 days after practice had ceased. The original practice had covered 42 days. In the relearning test, covering 11 days, the original speed was regained and exceeded. A score of 1600 was made as against a score of 1051 in the earlier work. Swift reports that the work was done in the last test "with greater skill, greater ease."

Swift thinks that such experiments as these prove that learning is to some extent a growth, that learning goes on after practice has ceased. Book, on the other

hand, thinks the facts can be explained by the disappearance of interfering associations. There is no question in either experiment that forgetting had taken place. When Book sat down for his first memory test, he had forgotten the key board, *but he quickly relearned what he had forgotten.* The fact seems to be that when learning is carried to a high degree of perfection, when it has required a large number of repetitions, it persists with great tenacity. It may be that the associative connections begin to lose strength at once, but they can be easily re-established and restored to their former strength.

Hill found that three years after learning mirror writing, skill was nearly as good as at the start and very soon regained. In three or four days of practice the skill originally acquired in 48 days of practice was regained. The author has also noted the peculiar persistence of the ability to do mirror writing once it has been mastered. Most people can learn to do mirror writing in an hour, try it no more for a year, and then find themselves able to do it.

Perhaps a related fact was that found by Downey and Anderson that there is "considerable retention of capacity to maintain two processes (reading and writing) after lapse of practice for more than two years, with a rapid relearning and approximation of one's last record." However, in both these cases, it is not so much a matter of having established a number of bonds, as having acquired a principle of procedure or attitude, or perhaps a method, a new way of taking the world. We learn this and get considerable practice in an hour or two, the results of which persist for a long time, but perhaps no longer than would a new idea that had a similar amount of repetition.

Thorndike holds the opinion that associative bonds of the neuromuscular kind probably are better retained than bonds that are formed in ideational learning, and that the explanation is to be found in the fact that the bonds connecting ideas have their basis in the later developed, more instable parts of the brain. Such may be the case, but it is not at all sure. There are on an Underwood typewriter 46 keys. Book practiced striking these 46 keys for 60 days, an hour a day. For the last ten days of practice this gave an average of about 270 strokes for each key. In the 60 days of practice, each key was struck *many thousands of times.* In Swift's experiments the muscular movements involved in keeping two balls in the air were few. These muscular movements were repeated many thousands of times in the 42 days of practice. Owing to the immense amount of repetition in both of these experiments, it is no wonder that the bonds persisted. If we should practice as much in the case of ideational learning, who knows but that the associative bonds would be fully as tenacious? Suppose we should take a poem involving 46 words or 46 ideas and practice saying it for 60 days, and then after a year and a half relearn it, the results might be much similar to those of the experiments mentioned above. The reason why we seem to forget, in the case of ideas, faster than is the case in neuromuscular learning, is more probably because in the case of ideational learning practice in fixing bonds is insignificant in amount when compared to practice in the case of motor learning. We study a lesson once, or at most, a few times. We hear a lecture once. Perhaps the facts of the lecture are reviewed a time or two. We

could not expect the fixation in such learning to compare favorably with motor learning involving hundreds, perhaps thousands of repetitions.

The facts available do not enable us to settle the matter of the relative persistence of ideational learning as compared to motor learning. But the facts do enable us to say that the strength of ideational bonds could be much increased by more repetition.

The results of motor learning suggest that great improvement is possible in ideational learning. This improvement is in the direction of association, organization, repetition. Some people seem to have the idea that if a thing is well learned once, it is learned for all time. Such is not the case. The only way known to fix and perpetuate a neural bond of any kind is by repetition. It makes no difference whether the bond is one connecting ideas, or stimulus and response, the facts are the same. Poems and songs that are learned in childhood through countless repetitions persist through life, or at least can be quickly and readily relearned. The tables which we learn in childhood by countless repetitions also persist in our minds. In all cases of ideational learning involving a great number of repetitions, retention is good over long periods of time.

Relation of Memory to Intelligence.—The relation of memory to intelligence has been determined in various ways: (1) Many investigators have compared pupils' standing in logical memory tests with their standing in school studies. The relation is found to be positive, those having good retention standing well in their studies, and those having poor retention standing low in their studies. The relation is not absolute, of course,

but high and positive. The author has found the correlation to be as high as .76 in the upper grades.

(2) Standing in logical memory tests has been correlated with other mental tests. The author has obtained the following correlations:

TABLE 19.

CORRELATION OF LOGICAL MEMORY TEST WITH SIX OTHER MENTAL TESTS.

With	r.	P. E.
Rote memory	.44	.049
Substitution	.26	.026
Opposites	.77	.033
Free Association	.41	.069
Word building	.53	.059
Completion	.77	.034
Average of six	.64	.049

It is evident from the table of correlations that logical memory has a high positive relation to other aspects of intelligence, giving the highest correlation with completion, the best single measure of intelligence so far devised.

(3) If all the children of the same age in any school system are compared with reference to their logical memory, those having the better memory are found in the higher grades as shown in Fig. 17.

All psychologists who have seriously investigated the relation of memory to intelligence have found the facts as stated above. For example, Lyon, after years of experimental study of memory, says:[3] "The students who stand highest in their various studies, and who prove upon examination to be the most intelligent, have, as a rule, the best memories. They not only learn more quickly, but they retain better." Winch in his extensive studies of the memories of London school children, came to the same conclusion, as have Bolton, Bourdon,

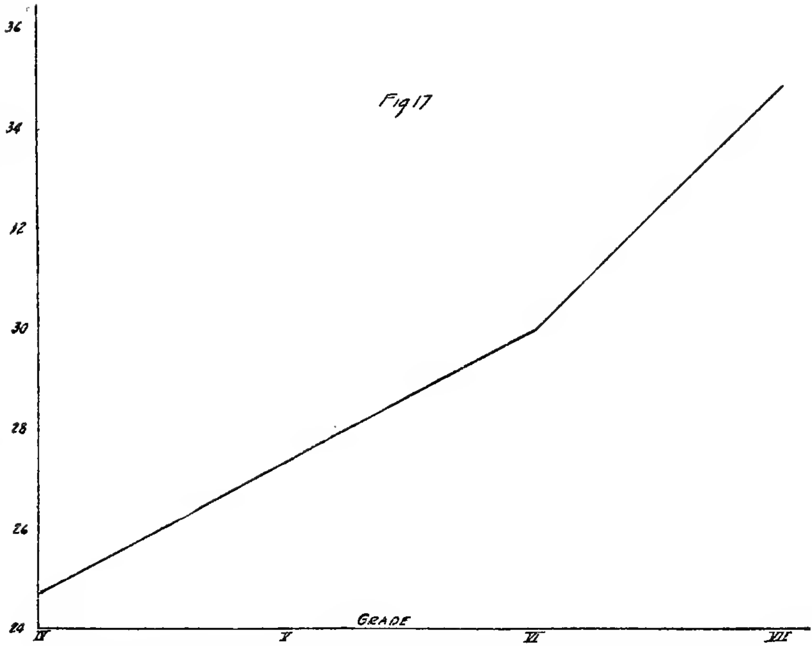

FIGURE 17. The graph shows the logical memory efficiency of twelve year old children in the fourth, fifth, sixth, and seventh grades.

Pohlmann, and many others. It is interesting to note here that Winch also found a positive correlation between ability to memorise stories and the ability to invent stories, the correlation being higher with the more intelligent.

When we say memory has a high relation to intelligence, we mean particularly logical memory. People of low intelligence may have good rote memories, may remember well discrete material, but only the intelligent have good memory for logical material. The unintelligent have no comprehension of *significance.* Such comprehension is necessary in logical memory. Some teachers have the mistaken notion that a good memory is to be deplored, that children should *understand* rather than *memorise,* that children should *reason things out.* But one cannot reason unless one remembers the facts of experience. Remembered ideas are the raw material of thought. Other things equal, the one who remembers best can reason best. Of course, remembering things without knowing their significance is of little value, but we must remember if we are to know their significance.

Individual Differences in Retentiveness.—Individual differences in the various aspects of memory are very great. The author once determined the logical memory of 100 high school students and found the best memory to be four times as good as the poorest. The distribution of 1032 university students is shown in Fig. 18. The test on which the graphs of the figure are based is the *Marble Statue.* The records, as represented on the horizontal axis of the figure, are for the number of ideas correctly reproduced after hearing the story read.

The number of students represented is 516 men and the same number of women.

The range of ability in rote memory is not quite so great as shown in Fig. 19. The graphs are based on measures of 419 university men and an equal number of women.

The differences in retentive capacity are thus seen to be very great. It is of very great consequence to a teacher to know that in an ordinary class retentive

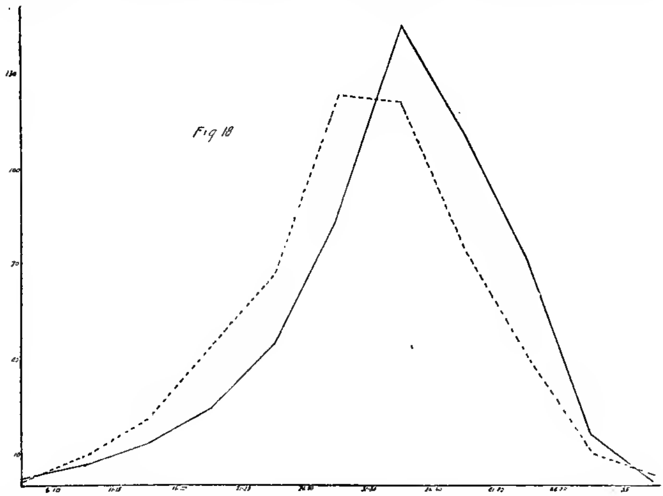

FIGURE 18. FREQUENCY SURFACES showing the distribution of 516 university men and the same number of women in logical memory efficiency; solid line women, broken line men.

capacity may be two or three or even four times as good in the best pupil as it is in the poorest pupil.

Different Aspects of Memory.—We have treated retention as if it were a definite characteristic of the nervous system. It probably is, but when we under-

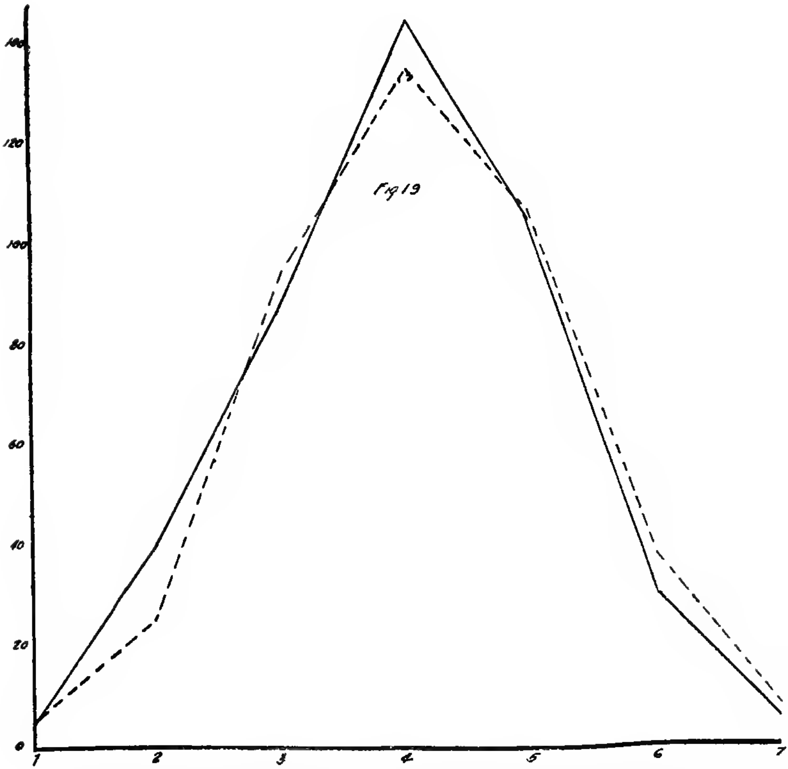

FIGURE 19. FREQUENCY SURFACES showing the distribution of 419 university men and the same number of women in rote memory efficiency.

take to measure it, we have to use some particular kind of impression, some particular stimulus, some definite kind of material. It turns out that we get different results from different kinds of material. We can not therefore treat memory as if it were a definite, unitary function. We must always speak of memory for this or that kind of material, presented in such and such manner, and tested in such and such way. It is probably true that our nervous systems have very definite capacities for retention, different for different people, but our various interests, and attentions, and prejudices, our various experiences with their different consequences, bring it about that different things make very different appeals to us. As a result, our retention of one type of impression may be very different from our retention of another. If a group of people are measured to ascertain their retention of various types of material, such as numbers, letters, objects, words, sentences, or the ideas of some selection of prose or poetry, it is found that their relative standing is not the same. Indeed, their retention of several different selections of meaningful material will vary. The author has twice computed the intercorrelation between the various pairs of measures for four different logical memory tests. In the first experiment, the intercorrelations were .379, .524, .555, .556, .568, .590. The average of these correlations is .5287, and the average P. E. is .089. In the second experiment, the correlations were .545, .559, .550, .518, .617, .476. The average is .5441, and the average P. E. is .074. For raw correlations in any sort of mental tests, these are high, and we may conclude that the relative ranks of individuals in logical memory tests will be about the same unless

some are specifically favored by the type of material. Thorndike found the correlation between memory for words and memory for numbers to be .45, and the correlation between immediate memory for words and delayed memory—24 hours later—to be .55.

So called rote memory is of considerable importance in early education, and of some importance throughout life. Rote memory has a positive correlation with logical memory but it is not very high. The average raw correlation is .355. The true correlation being about .53.

There are two definitely different aspects of memory. One we may call retention; the other, organisation. By retention, we mean the after-effects of nervous excitation, the persistence in the brain of the effects of neural activity. By organisation, we mean the associative connections between the separate impressions. These associative connections are the basis of recall. For the practical purposes of life, not only must impressions be retained, but we must be able to recall them. The significant thing for life is therefore logical memory, and it depends on more than mere retention. It depends on organisation, on meaning. Our ability to organise our experience in helpful ways depends on our capacity to see the significance of experience, and this is something entirely apart from retention. Indeed, our simple retention may be good while we entirely lack the power of organisation. Organisation can not exist without retention, but we can have a high degree of retentive capacity and lack the power of organization. A low type of mind may have an experience as rich as that of a Newton, and retain that experience as well, but lacking the power of organisa-

tion, the person uses this experience to no advantage because there are no helpful, meaningful associations in it.

Immediate and Delayed Memory.—The problem here is virtually the same as that discussed above under the head of relation of learning to retention, for the immediate memory span is taken as the measure of quickness of learning. We shall cite here no further evidence of the relationship, but merely recall that it was said that the quick learner is in general good in retention also. We may here put the matter in a somewhat different way. Suppose we present a given amount of matter to a group of people and find what amount of the matter they can immediately reproduce, then a day later, or a month later, we ascertain how much of the matter is still retained, we find in general that those who had the most facts immediately after the presentation still have the most facts. In any particular experiment, the relation will not be found perfect and absolute, because it is impossible to keep the conditions equal. The matter will come back to the minds of some and be repeated more than will be the case with others. Their retention will consequently be better relatively.

Measurements of Retention.—There are three main methods of measuring retention. (1) *The reproduction method.* By this method, we determine the amount of material previously learned that can be recalled. This is the most widely used method of measuring retention, and it is the test which the practical affairs of life put upon us, for no matter how easily we could relearn the material, no matter how much of it is just below the conscious level, if we can not recall it, it is not immediately available, and does us no more good for the

moment of need than if it were in no sense retained. (2) *The relearning method.* By this method we really measure the amount forgotten by the time required to relearn. The procedure is to learn a certain material to the point of just being able to reproduce it, and then later determine how much time is required to relearn the amount forgotten. The relearning time is taken as the measure of the amount forgotten and is inversely related to the amount retained. A relatively short relearning time indicates a good memory. This is probably a better method of measuring absolute retention than is the reproduction method, for it gives weight to any retention, no matter how vague or how faint. The reproduction method emphasises organisation, for recall depends on organisation and, as said above, for the practical purposes of life is perhaps more useful than the relearning method. (3) *The recognition method* By this method we do not have the subject either recall or relearn but recognise a previously experienced stimulus. The method may be illustrated by Strong's advertisement experiments. Strong presented to his subjects a certain number of advertisements and later presented these same advertisements along with many others. The subjects were to say whether each advertisement had been seen before or not. It is evident that the one of these methods we should use in any given case would depend upon our purposes.

Usually we are most interested in the logical memory of our students. This can be accurately measured by the form of tests now in use for this purpose. The procedure is to divide a story into ideas or units. The story is read to the subjects and, for immediate memory, we then require a written reproduction of the

story. In scoring it, we give credit for each idea adequately reproduced. Another method is to have the subjects answer a number of questions concerning the story. This procedure makes the grading of the work easier and more accurate. The questions can be so constructed that they can be answered in each case by a single word.

The best standardised method of measuring rote memory is as follows: Prepare six lists of words of one syllable each. Put three words in the first list, four in the second, five in the third, six in the fourth, seven in the fifth, and eight in the sixth. The first list is read to the subjects and an immediate reproduction required. The second list is then read and an immediate reproduction required, and so on to the eighth list. We can score the reproduction by giving one credit for each word reproduced without regard to position in the list, or we can give credit for the word and one credit for its position. The results are about the same, and of course, the former method is much simpler and easier.

Recognition.—A few facts have been discovered in the study of recognition memory that should be mentioned. Myers found recognition memory to be about two-and-a-half times as efficient as recall, and the correlation between the two to be low. For boys, recognition was three times as efficient as recall and for girls recognition was only twice as efficient. But girls were more efficient in recognition than were boys.

Strong studied the effect of the time interval upon recognition. The procedure was to present 20 words and then later present the same 20 along with 40 others. He tried different intervals up to 42 days. In immediate

recognition, 84% were recognised. After 7 days, only 10% were recognised. The decrease was rapid at first, then slow, as it has been found to be in other tests of memory.

Voluntary Recall.—Until matter is well learned, attempt at voluntary recall is a hindrance and a waste of time, but after matter is learned, voluntary recall has great value just as re-presentation has great value in fixing the material. Myers has studied the former of these factors. To 332 subjects he gave four series of tests, presenting orally ten words in each series. He found a decided gain in final recall as a result of intervening recall without re-presentation of the stimuli The effects of recall were greater if recall took place five minutes after presentation than when recall was immediate. This is in harmony with Jost's law—that repetitions have greater value for the older associations.

Guillet showed the value of presenting matter again two to five days after first presentation. Both recall and re-presentation are valuable. Which we should use at any particular stage of learning depends upon the kind of material and how far learning has progressed.

As long as learning is uncertain and doubtful, re-presentation is preferable. When recall is easily possible, recall is preferable. The importance for permanent fixation of re-presentation and recall can not be overestimated. In the practical work of studying our lessons, we should learn the material of the lesson; then after an interval of some hours go over the matter again; then after another interval go over the matter in the process of recall; then with longer and longer

intervals go over the matter again and again, using re-presentation or recall as the conditions demand.

In poor learning, as Myers has pointed out, the wrong elements become coupled together in recall. We should not try to recall when this is likely to happen. The remedy for poor learning is re-presentation, drill, better organisation.

Position in Series.—Numerous experiments have shown that in committing to memory a series of words, letters, or other items, the first ones and the last ones are learned first. Dell considered the matter with reference to meaningful material. He found that, other things being equal, the beginning and end of material were learned first. Generally speaking, other things are not equal; other factors are usually more important than position in series. Logical and systematic arrangement are probably more important. If we can combine logical and systematic arrangement with putting important items at the beginning and end, the results will be favorable.

Cramming.—Cramming may be defined as the learning or trying to learn a great amount of material in a short time. It is a legitimate process in two definite situations. If one has to organize a large amount of material for a particular occasion, it is legitimate and economical to concentrate the learning and do it all just before the knowledge is needed. Secondly, in the learning of material that is to be organised and remembered for life, or for a long period of time, the economical procedure is to spread the learning out, and occasionally to go over in concentrated fashion the whole of the material, for example, go over a whole book in one evening. This concentrated consideration of a large amount

of material helps one to see each part in the light of other parts. By the very process of being considered together, facts become related in memory. The oftener we can think over bits of experience that belong together, and that are needed together for use, the better these bits become cemented in memory, and the more likely one idea will be to recall the other related ones. The cramming process is not effective for lasting memory, however, unless there has previously been learning of the parts in detail. A bird's eye view of a lot of material is profitable provided we have previously had a microscopic view.

EXPERIMENTS AND EXERCISES.

1. The logical memory of all the students in the class should be determined by giving at least four tests, on the order of Whipple's *Marble Statue* test. The instructor should select four short passages of prose that are likely to make a strong appeal to all members of the class. Divide the passage up into its ideational units for ease in scoring. Read each passage and give plenty of time for each student to reproduce it. The score should be the number of ideas adequately reproduced. Combine the scores of the four tests to obtain each student's logical memory efficiency. Compute the intercorrelations, six in all, to determine the co-efficient of reliability of the tests.

2. Determine each student's rote memory for words by using lists of one syllable words, the lists ranging in length from five words to eight. Make at least four such tests. Determine the co-efficient of reliability as in experiment 1 above. Determine each student's standing by combining the results of the four tests, and

correlate the results with those from the logical memory tests.

3. Make a study of memory for objects in the following way: Select four groups of objects, ten in each group. Conceal them from the class. Expose the objects of each group serially, one at a time, and require the students to write down the names of the objects, without regard to the order of presentation. Combine the four records for the total score. Determine the coefficient of reliability as above, and correlate the combined scores with those in the two tests above.

REFERENCES.

Allin, A. M., *Recognition*, A. J. P., VII, 1896, 249.

Angell, J. R., *Meaning in memory and in attention*, P. R., X, 1903, 267.

Baldwin, J. M. and Shaw, W. J., *Memory for square size*, P. R., II, 1895, 236.

Bean, C. H., *The curve of forgetting*. Arch. of Psych., XX, No. 3, 1912.

Bennett, F., *The correlations between different memories*, J. Exp. P., I, 1916, 404.

Bergstrom, J. A., *Experiments upon physiological memory by means of the interference of associations*, A. J. P., V, 1892, 356.

Effect of changes in the time variable in memorising, together with some discussion of the technique of memory experimentation, A. J. P., XVIII, 1907, 206.

Burnham, W. H., *Retroactive amnesia, illustrative cases and a tentative explanation*, A. J. P., XIV, 1903, 382.

Memory, historically and experimentally considered, A. J. P., II, 1888, 39. See also, II, 568.

Bigham, J., *Memory*, P. R., I, 1894, 453.

Bolton, T. L., *The growth of memory in school children*, A. J. P., IV, 1891, 362.

Bolton, F. E., *The accuracy of recollection and observation*. P. R., III, 1896, 286.

Calkins, M. W., *Short studies in memory and in association*, P. R. V., 1898, 451.

Chamberlain, A. H., *A memory test with school children*. P. R. XXII, 1915, 71.

Collgrove, F. W., *Individual memories*, A. J. P., X, 1899, 228.

Cowan, E. A., *An experiment on the influence of training on memory*, J. E. P., VII, 1916, 31.

Dearborn, G. V. N., *Recognition under objective reversal*, P. R., VI, 1899, 395.

Dell, J. A., *Some observations on the learning of sensible material*, J. E. P., III, 1912, 401.

Downey, J. E. and Anderson, J. E., *Retention of skill after lapse of practice*, A. J. P., XXVIII, 1917, 396.

Ebbinghaus, H., *Memory*, 1885, Tr. by H. A. Ruger, 1913.

Finkenbinder, E. O., *The curve of forgetting*, A. J. P., XXIV, 1913, 8.

Gates, A. I., *Experiments on the relative efficiency of men and women in memory and reasoning*, P. R., XXIV, 1917, 139.

Recitation as a factor in memorising, Arch. of Psych., No. 40, 1917.

Correlations of immediate and delayed recall, J. E. P., IX, 1918, 489.

The mnemonic span for visual and auditory digits, J. Exp. P., I, 1916, 393.

Guillet, C., *A study of the memory of young women*, J. E .P., VIII, 1917, 65.

Retentiveness in child and adult, A. J. P., XX, 1909, 318.

Hall, G. S., *Note on early memories*, Ped. Sem., VI, 1899, 485.

Hawkins, C. J., *Experiments on memory types*, P. R., IV, 1897, 289.

Hayden, E. A., *memory for lifted weights*, A. J. P., XVII, 1906, 497.

Henderson, E. N., *A study of memory*, P. R. Mon. Sup., No. 23, 1903.

Henmon, V. A. C., *The relation between mode of presentation and retention*, P. R., XIX, 1912, 79.

The relation between learning and retention and the amount to be learned, J. Exp. P., II, 1917, 476.

Hill, D. S., *Minor studies in learning and relearning*, J. E. P., V, 1914, 375.

Hollingworth, H. L., *Characteristic differences between recall and recognition*, A. J. P., XXIV, 1913, 532.

Kennedy, F., *On the experimental investigation of memory*, P.R.V., 1898, 477.

Kirkpatrick, E. A., *An experimental study of memory*, P. R., I, 1894, 602.

Kuhlmann, F., *The place of mental imagery and memory among mental functions*, A. J. P., XVI, 1905, 337.

Lyon D. O., *The relation of quickness of learning to retentiveness*, Arch. of Psych., No. 34, 1916.

Mulhall, E. F., *Tests of the memories of school children*, J. E. P., VIII, 1917, 294.

Münsterberg, H. and Bigham, J., *Memory*, P. R., I, 1894, 34.

Myers, G. C., *A comparative study of recognition and recall*, P. R., XXI, 1914, 442.

Recall in relation to retention, J. E. P., V, 1914, 119.

Confusion in recall, J. E. P., VIII, 1917, 166.

Norsworthy, N., *Acquisition as related to retention*, J. E. P., III, 1912, 214.

Patterson, T. L., *Pedagogical suggestions from memory tests*, J. E. P., IX, 1918, 497.

Perkins, N. L., *The Value of distributed repetitions in rote learning*, B. J. P., VII, 1914-15, 253.

Peterson, H. A., *On the influence of complexity and dissimilarity on memory*, P. R. Mon. Sup., No. 49, 1909.

McC. Gamble, E. A., *A study in memorising various materials by the reconstruction method.* P. R. Mon. Sup., No. 43, 1909.

Pohlmann, A., *Experimentelle Beiträge zur Lehre vom Gedächtnis*, 1906.

Potwin, E. B., *Study of early memories*, P. R., VIII, 1901, 596.

Pyle, W. H., *One function of the teacher in memory work*, J. E. P., I, 1910, 474.

The most economical unit for committing to memory, J. E. P., II, 1911, 133.

Retention as related to repetition, J. E. P., II, 1911, 311.

Shaw, J. C., *A test of memory in school children*, Ped. Sem., IV, 1896, 61.

Smith, W. G., *The Place of repetition in memory*, P. R., III, 1896, 21.

Smith, M. and McDougal, W., *Some experiments in learning and retention*, B. J. P., X, 1920, 199.

Smith, T. L., *On muscular memory*, A. J. P., VII, 1896, 453.

Stetson, G. R., *Some memory tests of whites and blacks*, P. R., IV, 1897, 285.

Strong, E. K., Jr., *The effect of time interval upon recognition memory*, P. R., XX, 1913, 339.

The effect of length of series upon recognition memory, P. R., XIX, 1912, 447.

Swift, E. J., *Memory of a complex skillful act*, A. J. P., XVI, 1905, 131.

Thorndike, E. L., *Memory for paired associates*, P. R., XV, 1908, 122.

The relation between memory for words and memory for numbers and the relation between memory over short and memory over long intervals, A. J. P., XXI, 1910, 487.

Titchener, E. B. and Talbot, E. B., *An attempt to train the visual memory*, A. J. P., VIII, 1897, 414.

Tolman, E. C., *Retroactive inhibition as affected by conditions of learning*, P. Mon., No. 107, 1917.

Watkins, S. H., *Immediate memory and its evaluation*, B. J. P., VII, 1914-15, 319.

Whitehead, L. G., *A Study of visual and aural memory processes*, P. R., III, 1896, 258.

Winch, W. H., *Some relation between substance memory and productive imagination in school children*, B. J. P., IV., 1911, 95.

Immediate memory in school children, B. J. P., II, 1906, 52.

Immediate memory in school children, B. J. P., I, 1904, 127.

CHAPTER VIII.

THE NATURE OF LEARNING CAPACITY.

Our problem is now to enquire into the nature of learning capacity. The question which we shall try to answer is this: Are the characteristics of the nervous system such that a person may be spoken of as a "good learner" or a "poor learner" in general? Or must we say that a person is good at learning one type of material and perhaps poor at learning other types? Must we say that a certain person can learn mathematics easily, but learns some other subject, let us say history, with difficulty? Or can we say that a person is a good learner or a poor learner at whatever he undertakes to learn? In the schools, for example, is a person known as a *good* student or a *poor* student in general, or is he known as a good student in history and language, for example, and a poor student in science and mathematics? Generally students are spoken of as *good* or *poor* without reference to any particular subject of study. There are, however, numerous exceptions. Sometimes a student is known as an excellent student in science and as a poor student in language. In such cases the question arises whether the explanation may not be quite other than difference in ability to learn the different subjects. The explanation may be found in difference in preliminary training, difference in interest, and other factors of experience.

The question which we have raised in this chapter is of the highest importance to education, for if learning, whatever its nature, depends upon fundamental characteristics of the brain and nervous system, then it will be found a comparatively simple matter to determine by experiment the learning capacity of the pupils in the public schools and of students in the colleges. On the other hand, if learning is a specific matter, we can not speak of learning capacity in a general sense, but must speak of ability to learn this or that. But let us turn to the experiments.

Interrelation of Different Learning Capacities.—We shall first consider extensive experiments performed in the author's laboratory with several different kinds of material. The learning falls under four different types. (1) First, what we may call motor learning, consisting of card sorting and marble sorting. The card sorting consisted in distributing 150 numbered cards into trays numbered correspondingly. There were 30 trays arranged with five in a row, and in six rows. There were therefore five cards to each tray. An experiment consisted in distributing the 150 cards into their appropriate trays. In marble sorting 96 marbles of different colors and sizes were distributed into six different receiving boxes by means of a complicated machine demanding the use of both feet and both hands. (2) The second type of learning is what we may call semi-motor in character, the substitution experiments. There were three types of these experiments, turning digits into symbols, turning symbols into digits, and transcribing the alphabet into an arbitrary symbol alphabet. The former two we shall call the digit substitution experiment and the latter the alphabet substi-

tution experiment. The essential difference in these experiments was that in the digit substitution experiments, there were only nine bonds to form, while in the alphabet substitution experiment there were twenty-six bonds to form. In the substitution experiments while there was a motor element, it was not so important as in the sorting experiments, and the ideational element was of more importance. (3) The third type of experiment we may call ideational, because the motor element was relatively unimportant. In this experiment series of ten nonsense syllables were learned. They were exposed visually in series of ten, one second exposure to each syllable. The exposure of the syllables was continued until the subjects could write them in their proper order. (4) The fourth type of learning we may call motor-inhibited. It consisted in learning mirror writing. The method consisted in learning to write, with a mirror-reflected stimulus, letters that appeared normal in the mirror. It will be seen that these experiments were widely different in type. Even the two we have called motor were widely different. In the case of card-sorting, simple associations had to be built up between numbers and places. There were 30 such associations. In marble-sorting, the matter was much more complicated. Appropriate responses had to be learned for marbles of four different colors and two different sizes, only six in all, but there were four different holes for the reception of the marbles, and the feet had to manipulate pedals when certain marbles were deposited. Most of the experiments were repeated with several different groups of students. There were usually about 75 in a group. The

learning capacity of each student for each type of learning was determined, and all the possible correlations were computed, 41 in all. The results were very constant. Only the averages will be given here. In table 20 are shown the average correlations of each type of learning with all other types.

TABLE 20.

SHOWING THE AVERAGE CORRELATION OF EACH OF FIVE TYPES OF LEARNING WITH OTHER TYPES.

Type of Learning.	Average of Correlations.
Digit substitution	.594
Alphabet substitution	.547
Nonsense syllables	.441
Card sorting	.496
Marble sorting	.503
Average of all	.516

Only one correlation could be computed with mirror writing, and that was with learning nonsense syllables. Between these two tests, the correlation was .505, and is included in the averages as given for nonsense syllables.

What is the significance of these correlations? A raw correlation of a little more than .5 indicates a very high positive relationship between the abilities required to learn the different types of material. But if learning capacity is general, should not the correlation be unity? In the author's opinion, if the disturbing factors could be eliminated, the correlation would be unity. There were several disturbing factors. In the first place, the score obtained was not always a correct indication of quickness of learning. In card-sorting there were wide differences in ability to manipulate the cards which affected the score but had no relation to ability to learn. These differences in facility with the cards

were due to past experience. Another factor which affected the score but had no relation to capacity to learn was attitude toward the different experiments. Owing to difference in interest, students would try much harder in some experiments than in others. Previous experience, then, affected the scores through giving the students some advantage or disadvantage and through their effects on the students' attitude and interest. In motor learning, reaction time, which probably has no relation to ability to learn, affected the scores. We conclude that as far as these learning experiments furnish evidence, learning capacity is a general characteristic.

Evidence From Memory Experiments.—Experiments in immediate memory are virtually experiments in ability to learn, and their results throw light on our present problem. In Table 21 are shown the intercorrelations among four logical memory tests. Each memory test was given to two separate groups of students. This made possible two complete sets of correlations, twelve in all. The different correlations together with the averages are shown in the table. The four tests were *The Dutch Homestead, Cicero,* and *Marble Statue* from Whipple, and *The Costly Temper* from the author's "Manual."

The intercorrelations of the memory tests, .537, is but a trifle more than the intercorrelations of the learning tests. Ability to reproduce stories heard is certainly as nearly a unitary function as one could imagine, still the correlations between story reproductions are practically the same as the correlations among widely different types of learning.

TABLE 21.
SHOWING THE INTERCORRELATIONS OF FOUR DIFFERENT TESTS OF LOGICAL MEMORY.

	Costly Temper.	Dutch Homestead.	Cicero.	Marble Statue.
Costly Temper	....	.524 .617 .571	.568 .559 .564	.556 .518 .537
Dutch Homestead	.524 .617 .571	....	.555 .545 .550	.590 .476 .533
Cicero	.568 .559 .564	.555 .545 .550	....	.379 .550 .465
Marble Statue	.556 .518 .537	.590 .476 .533	.379 .550 .465	....
Average	.557	.551	.526	.512

Average of the four averages is .537.

In Lyon's memory studies we find correlations computed for five different types of memorising. In one series of studies with 24 subjects he found an intercorrelation of .51; and in another study with 17 subjects he found a correlation of .42. His correlations were computed by the rank-difference method. His results are therefore about the same as those reported above. His correlations for different types of memorising are practically the same as those in logical memory.

Regularity of Learning. — Few characteristics of learning are more remarkable than its regularity in the same individual. Two instances will be sufficient for illustration. In an experiment in learning lists of 26 nonsense syllables, the number of repetitions necessary to learn them to the point of first reproduction was determined. The number of repetitions necessary for relearning on succeeding days was also determined. It

was found that relearning time had a very definite relation to learning time and this ratio was fairly constant and about the same for all subjects. While the experiment threw no light on the matter of learning different types of material, it showed great definiteness and constancy in learning the same kind of material. The other illustration is from card-sorting. In this kind of learning, nothing was more noticeable than the definiteness and regularity of the different subjects. They retained their relative positions or ranks from day to day with great constancy. At the beginning of an experiment the experimenter could predict, on the basis of the previous day's work, the relative ranks of the subjects. The learning capacity of the various learners became definitely known to the experimenter. The characteristics underlying learning capacity seem to persist and to be as definite as anything in human nature. Such variations as usually occur in a given subject's learning from day to day, have definite causes and can be predicted when the causes are known. Of course, constancy in learning depends upon constancy of the conditions and factors involved. These factors are numerous. The condition of nearly every organ in the body can have its effect on the temporary efficiency of the learner. But there is probably a constant factor which may be called general learning capacity, dependent upon the characteristics of the central nervous system.

Interrelation of Mental Functions.—The question of the relations of different types of learning capacity raises the more general question of the relation of all mental functions. The question may be put in this way: Are mental functions positively or negatively related? Or is there any dependent relationships among them at

all? If the efficiency of one mental function is known, can we predict the efficiency of others? These questions can be answered with some degree of certainty. The answer comes from mental tests given in various countries during the last twenty years. We shall show certain typical results and then discuss their significence. In table 22 are shown the intercorrelations for a group of mental tests given to three different groups of students in the author's laboratory. There were 21 correlations for each group, 63 correlations in all. Only the averages are shown in the table.

What is the significance of the figures shown in the three tables of correlations? In table 22 the correlations are all positive but one. Free association gives with substitution a negative correlation. It is small, however, and may be considered zero. The averages of all the correlations, although small, are positive. A careful study of all the correlation tables published shows that all important complex mental functions are positively related. The raw correlations are never very high. The disturbing factors are so many that we can

TABLE 22 (PYLE).

SHOWING THE INTERCORRELATIONS AMONG DIFFERENT MENTAL FUNCTIONS.

	Completion.	Logical Memory.	Opposites.	Rote Memory.	Word Building.	Free Association.	Substitution.
Completion	.382	.546	.522	.357	.286	.177	.274
Logical memory	.546	.523	.291	.436	.232	.261	.122
Opposites	.522	.291	.558	.154	.438	.165	.240
Rote memory	.357	.436	.154	.655	.022	.265	.016
Word building	.286	.232	.438	.022	.654	.200	.050
Free association	.177	.261	.165	.265	.200	.679	—.027
Substitution	.274	.122	.240	.016	.050	—.027	.805
Averages	.330	.315	.302	.208	.205	.174	.113

TABLE 23 (FROM BURT).

SHOWING THE INTERCORRELATIONS (CORRECTED CO-EFFICIENTS) IN THE CASE OF THE MORE COMPLEX MENTAL FUNCTIONS TESTED.

	Spot Pattern.	Dotting.	Mirror Tracing.	Alphabet.	Memory.	Dealing.
Spot pattern	......	.80	.75	.96	.41	.66
Dotting	.80	......	.84	.85	.22	.83
Mirror tracing	.75	.84	......	.71	.13	.72
Alphabet	.96	.85	.71	......	.47	.83
Memory	.41	.22	.13	.47	......	.18
Dealing	.66	.83	.72	.83	.18	......
Averages	.72	.71	.63	.76	.28	.64

TABLE 24 (FROM SIMPSON).

SHOWING THE ESTIMATED TRUE CORRELATION FOR PEOPLE IN GENERAL, I. E., THE PROBABLE CORRELATIONS AS THEY WOULD BE IF THE SUBJECTS WERE A VERY LARGE NUMBER OF PERSONS REPRESENTING A RANDOM SAMPLING OF ALL THE PEOPLE, INSTEAD OF TWO SMALL, SELECTED GROUPS.

	Ebbinghaus Completion.	Hard Opposites.	Memory for Words.	Memory for Passages.	Learning Pairs.	Completing Words.
Ebbinghaus completion	......	.85	.82	.71	.60	.60
Hard opposites	.85	......	.84	.70	.56	.72
Memory for words	.82	.84	......	.80	.65	.61
Memory for passages	.71	.70	.80	......	.30	.31
Learning pairs	.60	.56	.65	.30	......	.44
Completing words	.60	.72	.61	.31	.44	......
Averages	.72	.73	.74	.56	.51	.54

never expect to get a very high correlation between any two different mental functions. In table 22 it is seen that the raw correlation between two successive tests of the same kind is not nearly unity. In the seven tests they range from .382 to .805, the average being only .608. This last coefficient indicates the reliability of our measure, for, of course, the true correlation is not .608 but unity. The average *raw* correlation in this table is .239. The average *true* correlation would be about .40.

We said above that all important mental functions are positively related. This is not quite the truth. What we should say is that all mental functions which may be considered a part of general intelligence, general mental ability, are positively related. For, of course, it is not true that any aspect of human behavior that we may measure will be found positively related to all other aspects of human behavior. Quickness of reaction time, for example, probably has no relation to intelligence. Rapidity in running has no relation to judgment of color. Strength of grip has no relation to accuracy of ethical judgment. Now, a few performances that have been used as mental tests have given negative correlations with other tests. The author has found Whipple's ink-blot test, the free association test, and cancellation tests given for speed only, to show small negative correlations with certain other tests. These correlations are usually small, and probably should be considered zero, for they are sometimes positive. Some writers, Simpson for example, have attached some importance to these negative correlations. But their explanation is plain. Older children make poorer records in the ink blot test than younger children, on account of a change in attitude. If we make the test consist in ability to see objects in the blots, as children become older, they do not report many objects owing to their great sophistication. They will not admit that the blots look like anything. The free association test is little if any more than a test of quickness of nervous response, and this, as far as we know, has no relation to the value or quality of response. And in the cancellation test when we do not consider accuracy, we are measuring little more than reaction time. None of these three tests has shown any positive

relation to general intelligence otherwise determined, and none of these tests is of any value as a measure of intelligence. We repeat, in agreement with Thorndike, that no test that is a measure of general intelligence has a negative relation with any other such test. On the other hand, every test that has proven to be a high criterion of general intelligence, has shown high correlation with other such tests. Of all single tests, the completion test has proven to be the best measure of intelligence. This test gives the highest average correlation with other tests. The other tests of proven value as measures of general intelligence—opposites, logical memory and analogies—all give high positive correlations with other important tests. From this evidence, only one conclusion seems to us possible. There is a human characteristic which we may call general learning capacity, just as there is another which we may call general intelligence.

Specific Abilities.—We have a general learning capacity. We are quick learners, slow learners or mediocre learners. But when we learn, we work with some particular kind of material. There are therefore two additional factors that must always be taken into account besides the general factor. One of these factors involves the specific characteristics necessary to some type of learning. For example, in music, one will learn fast if he has a good general learning capacity and also those specific characteristics necessary to music, particularly ability to differentiate pitch, judgment of harmony and dissonance, perception of rhythm. In art, one might learn slowly although having good general learning capacity, because of lack of muscular control, or because of being color blind. In all learning requiring specific abilities, quickness of learning will depend

upon the degree of general learning capacity possessed and also upon the degree to which the specific abilities are possessed.

The other secondary factor that must always be taken into account is the effect of experience. In the realm of habit, when we start in to form a new one, we usually find some old habit that either helps or hinders, so that our speed of learning is affected by the old habit. And likewise in the realm of knowledge, the knowledge we have already acquired is of great consequence. Our learning is fast because of the previously acquired knowledge or slow because we do not have it. Great is the effect, also, of the attitude which previous experience gives us toward new tasks. Because of past experience we like certain things and dislike others, and these affective attitudes are of the greatest consequence in learning; helping if favorable and greatly hindering if unfavorable. If by any chance a pupil gets the idea that he can not do a thing, *he does not like that thing* and he does not try to do it. As time passes, his inability increases because of the increase of the force of the inhibition and also because of lack of practice. While we therefore have a general learning capacity, it never operates entirely freely but is always complicated by specific factors and by the effects of previous experience.

Nature of General Learning Capacity.—It is clear that specific learning capacity depends upon the possession of certain specific characteristics, such as reaction time, muscular co-ordination, quality of sense perception, and sensory discrimination, color sense, various auditory characteristics, ideational type, etc. But on what does general learning capacity depend? What the characteristics of the central nervous system on

which quick learning depends, are, we do not know. In psychological terms, however, something can be said of what characterises a quick learner. The quick learner has what is called in ordinary terminology, *the power of concentration.* All the available cerebral energy seems to participate in the learning; there is no waste of energy. This characteristic is what is usually spoken of as *power of attention.* The fact that good learners also remember well, and the further fact that good retention is known to depend upon the vividness and intensity of impression which are secured only in a high state of attention, lend evidence to the assumption that power to learn depends upon power to attend. Since attention is merely sensory clearness, it is probable that a low level of attention means a low level of mentality. The mental processes of the slow learner would, on this assumption, be more vague, less potent, more poorly knit together. Another characteristic that undoubtedly affects learning capacity is ability to perceive *significance.* This factor is particularly effective in the higher realms of intellectual learning, where meaning and organisation are the important things. All of us have about the same sensory experience; the good learner is he who knows what, in all this experience, is significant and what is not. The essential thing in intellectual learning is organisation. Organisation depends upon *knowing what and how to organise.* The good learner sees what characteristics of experience are significant for the purposes of his life, *he attends to these characteristics to the exclusion of unimportant characteristics.* The result is a helpful and useful organisation of the items of experience. As a consequence experience is more vital to the good learner, more useful in the after application to life's purposes and more help-

ful in learning other related things. The good learner, then, has available a large amount of cerebral energy which he can bring to bear in the learning process, and is able to recognise the significant and distinguish it from the unimportant. The result is a good organisation of what is useful. The poor learner lives on a lower intellectual level. His mental processes are more vague, more loosely knit together. The poor learner can not discriminate. One item of experience is to him about as important as another; there is therefore no selective attention, and as a result no helpful organisation of the items of experience. Experience is therefore of little use in the practical affairs of life or in learning.

In the very simplest of learning, these two factors can be seen to operate. Let us apply them to card-sorting. In the case of the quick learner, the mental power is all concentrated on the learning. There is no division of attention. The quick learner further sees significant and helpful connections and associations. He says, for example, "such a number is in the corner, another is in the middle, still another is by such and such a number," and so on. I have found that in nonsense learning, the fastest learners are always those that put meanings into the syllables, and hit upon various schemes of organisation. The poorer learners are dependent solely upon repeated presentation of the stimuli.

A General Mental Factor.—Our consideration of the nature of learning leads us to the question of the nature of general intelligence. We have found reason to believe that there is a general factor that operates in all learning, a factor which we call general learning capacity. Certain psychologists claim that there is *a gen-*

eral or central intellectual factor that participates in all intellectual activity. This central factor is claimed to be the chief basis of the positive correlation found between any two important intellectual activities. Spearman is the leading psychologist who advocates the central factor. The main item of proof of this factor is that in a table of correlations, if the correlations themselves are high and dependable, any two pairs of columns give a high positive correlation. This could be true, Spearman claims, only if there is a common factor in all the tests. Thorndike, Brown, Simpson, and others oppose this theory. Thorndike holds that positive correlation between two activities depends only upon some identity of the functions involved, a certain identity of processes. The evidence available does not make possible a present solution of this question. In the light of such evidence as we now have, I am inclined to believe that there is a general learning factor, and also a general intellectual factor, a factor operative in all intellectual processes. The general learning factor and the general intellectual factor are probably the same. We stated above that the general learning factor may be considered to be the power of attention. Burt made a similar claim for the general intellectual factor. But a high type of intellect, as pointed out above, possesses two characteristics, good learning ability and the ability to recognize significance. It may be that these two characteristics have a common basis. The physiological processes and the anatomical structures which underlie the psychological factors we have named and discussed are not known. About all we can say is that some brains are better for the important purposes of life than are other brains. Our brains probably have

general characteristics which are potent in all intellectual operations, hence, the general learning factor, and the central intellectual factor. But just as surely, brains have certain specific characteristics, effective in specific acts of behavior, characteristics that make one a better seer, or hearer, or taster, for example; characteristics that help or hinder in specific processes, and that must always be considered in connection with the general factor.

EXERCISES AND EXPERIMENTS

1. The object of this experiment is to determine to what extent learning capacity is general. Method: Compute the inter-correlations among all the learning experiments performed in this course. The experiments should include card-sorting, different forms of substitution, all the memory tests included in the exercises of Chapter VII, verbatim learning, learning nonsense syllables, and any other learning experiments performed with sufficient care to give valid results. How do the correlations compare with those reported in the chapter?

REFERENCES.

Aiken, H. A. and Thorndike, E. L., *Correlations among the perceptive and associative processes*, P. R., IX, 1902, 374.

Brown, W., *Some experimental results in the correlation of mental abilities*, B. J. P., III, 1910, 296.

Brown, W., *The essentials of mental measurement*, 1911.

Burt, C., *Experimental tests of general intelligence*, B. J. P., III, 1909, 94.

Chapman, J. C., *Individual differences in ability and improvement and their correlations*, T. C. Cont. to Ed., No. 63, 1914.

Cogan, L. G. and Conklin, A. M. and Hollingworth, H. L., *An experimental study of self analysis, estimates of associates and psychological tests*, S. and S., II, 1915, 171.

Dunlap, K., *The biological basis of the association of ideas and the development of perception*, Psychobiology, II, No. 1, 29.

Elderton, E. M., *On the association of drawing with other capacities in school children*, Biometrica, III, 1909-10, 222.

Haggerty, M. E., *The laws of learning*, P. R., XX, 1913, 411.

Hart, B. and Spearman, C., *General ability, its existence and nature*, B. J. P., V, 1912, 51.

Hollingworth, H. L., *Correlation of abilities as affected by practice*, J. E. P., IV, 1913, 405.

Individual differences before, during, and after practice, P. R., XXI, 1914, 1.

King, I, *The relationship of abilities in certain mental tests to ability as estimated by teachers*, S. and S., V, 1917, 204.

Kline, L. W. and Owens, W. A., *Preliminary report of a study in the learning process involving feeling tone, transference and interference*, P. R., XX, 1913, 206.

Krueger, F. and Spearman, C., *Die correlation zwischen verschiedenen geistigen leistungsfähigkeiten*, Zeit., f. Psych. Bd., XLIV, 1906, 50.

Lashly, K. S., *Studies of cerebral function in learning*, Psychobiology, II, No. 1, 55.

Lyon, D. O., *Memory and the learning process*, 1917.

The relation of quickness of learning to retentiveness, 1916.

McCall, W. A., *Correlation of some psychological measurements with special attention to the measurement of mental ability*, S. and S., V, 1917, 24.

Peterson, A., *Correlation of certain mental tests in normal school students*, P. R., XV, 1918, 323.

Pyle, W. H., *Standards of mental efficiency*, J. E. P., IV, 1913, 61.

Rietz, H. L., *On the correlation of the marks of students in mathematics and in law*, J. E. P., VII, 1916, 87.

Simpson, B. R., *Correlations of mental abilities*, T. C. Cont. to Ed. No. 53, 1912.

Spearman, C., *General intelligence objectively determined and measured*, A. J. P., XV, 1904, 201.

Manifold sub-theories of the "Two factors," P. R., XXVII, 1920, 159.

Starch, D., *Correlations among abilities in school studies*, J. E. P., IV, 1913, 411.

Thompson. G. H., *A hierarchy without a general factor*, B. J. P., VIII, 1916, 271.

Thorndike, E. L., *The effect of practice in the case of a purely intellectual function*, A. J. P., XIX, 1908, 374.

and Lay W. and Dean, P. R., *The relation of accuracy in sensory discrimination to general intelligence*, A. J. P., XX, 1909. 364.

Educational Psychology. Vol. III, 1914, 315.

Weglin, D. E., *The correlation of abilities of high school pupils*, 1917.

Whitley, M. T., *An empirical study of certain tests for individual differences*, Arch. of Psych., No. 19, 1911.

Wissler, C., *The correlation of mental and physical tests*. P. R. Mon. Sup., III, No. 16, 1901, 62.

CHAPTER IX.

MEASURING LEARNING CAPACITY.

In the last chapter we came face to face with the problem of measuring learning capacity, for in order to compare ability in one field of learning with ability in another, we must have some means of measuring capacity to learn. Since the question of measuring learning capacity is an important one and has many details that demand specific investigation, we have reserved its treatment for a separate chapter. Our problem here is but a part of the more general question of measuring all mental functions. Into the general question of mental measurements, we shall not enter. The possibility of such measurements and their practical feasibility have been fully demonstrated.

Learning is forming bonds between stimuli and responses or between ideas. Common observation as well as experiment shows that the rate and effectiveness with which we form these bonds vary from one person to another. In order to measure the efficiency of a learner we have but to set him a task of bond-forming and determine the amount accomplished in a given time; by comparing this amount with the results from other learners we can determine whether the learner being measured is fast or slow.

Such a procedure seems quite simple, as indeed it is. But before we can feel confidence in the results of such measurements, we must have information on several

details of the procedure. In the first place, if we are to compare the efficiency of one learner with that of another, the learners must not only be set the same task but each must work with all his might. If one learner puts forth all possible energy, and the other does not try, of course, the results are not comparable. A mental test of any kind is valid only on the assumption that the learner does his best. The validity of a mental test depends further on those tested being in good physical and mental condition. By good physical condition, we mean the subject must be free from fatigue, sickness or any other physical ailment that would interfere with learning. By proper mental condition, we have reference to emotion and attitude. The person being measured should not be excited unduly or nervous. A favorable attitude is always desirable, because it is necessary to get the subject to do his best. So much for the conditions required on the part of the subject. There are also certain problems of method that must be considered. In comparing the learning efficiency of different learners, we compare their learning curves. But what point in the curves shall we take for comparision? Shall we measure a group of learners which we wish to compare after they have worked a short time or after they have worked a long time? The results may be different. We do not know in the absence of experiment. We do not know whether some learners may start out slowly and become much faster later, while some may start out fast and become slower later. If we allow our subjects to work till they have reached their limit in the given task, and then measure them, we are evidently measuring final efficiency, which may be quite a different thing from learning capacity. For all we

know to the contrary, a quick learner may soon reach his limit while a slow learner may continue to improve and reach a final efficiency much greater than that reached by the fast learner. It is evident therefore that the length of time we allow our subjects to work before taking our measure is an important matter. These various questions of method we shall consider below. We must first see what sort of tests have been used as measures of learning capacity.

Learning Tests.—The type of learning test most extensively used is the substitution test, which is one of the simplest of tests and has a wide range of possibilities in the materials that can be used and the variations that can be made in them. The principle of the test is as follows: The learner is given a number of symbols with which he is familiar and is required to couple with these symbols others which have not been so coupled with them in the experience of the subject. In a form of the experiment standardised by the author, the known symbols are the nine digits, and the symbols that are to be coupled with them are letters of the alphabet. The procedure in giving the test is as follows: The subject is given the test sheet which contains columns of numbers, five digits in a number. After the numbers are five squares in which the proper letters are to be written. At the top of the test sheet is a key showing what letter is to be coupled with each digit. The child, after hearing an explanation of the nature of what he is required to do, proceeds at once to fill out the squares, looking up at the key to see how to do it. The theory of the test is that the quick learner will soon know the key and will not have to look at it; he therefore makes a higher score in a given time. As

the author has used the test, eight minutes were allowed in grades three, four, and five, and five minutes in the grades above. The score—indicating the learning capacity—is the number of correct substitutions made in a minute.

In practice, this test does not turn out to be just what it is in theory. The discrepancy consists in the fact that some subjects do not try to learn the key, but continue to refer to it throughout the experiment. Since these are the less intelligent pupils, the error is not so great as might be expected. Nevertheless a better way to administer a substitution test is to provide the subjects with the key and allow them to study it for a certain length of time, then require them to write the substitutions from memory. In Table 25 are the norms for public school children by age and sex; method, pupils using the key while practicing.

TABLE 25.

SUBSTITUTION TEST, CITY CHILDREN. METHOD—USING KEY WHILE PRACTICING. SCORE—NUMBER CORRECT SUBSTITIONS PER MINUTE.

	Boys		Girls	
Age.	No. Cases.	Average.	No. Cases.	Average.
8	223	7.95	213	9.11
9	296	10.08	355	10.86
10	410	11.81	386	13.82
11	443	13.43	387	15.88
12	399	15.48	433	18.29
13	401	16.80	424	20.31
14	308	19.26	344	22.21
15	255	22.13	274	24.17
16	173	23.71	217	26.92
17	93	26.42	141	28.12
18	52	24.41	86	28.39

The substitution test has a high co-efficient of reliability, and it gives the highest average correlation with the other learning tests, as shown in table 20. With the

other mental tests, it gives low but constant correlations. While it gives low correlations with the other types of mental tests, if its correlations with the other tests are themselves correlated with the averages of the correlations of each test with all the others as shown at the bottom of the correlation table (p. 165), it gives a higher correlation than any other test similarly treated. This indicates the most constant presence and regularity of the factor common to the tests.

Many different forms of the substitution test have been used. Their validity depends upon how they are given and how they are scored. If they are properly administered and properly scored, and repeated so as to give a stable measure, they give a measure of considerable reliability.

Tests of Motor Learning.—A motor learning test extensively used by the author and, in various forms, used in other laboratories, is the card-sorting test described in Chapter VIII. This test has many advantages. It has no relation to book-learning or any of the ordinary learning that goes on at school. By using playing cards or cards with colors instead of numbers it can be given to illiterates or very young children. The demands of the test are easily understood. By sorting into a small number of boxes, the learner soon gets sufficient data for the construction of a learning curve. The test practically always arouses interest and the subjects do their best. Its only disadvantage is that in the case of older subjects, those who are adept in the handling of cards, make a somewhat higher score than they otherwise would.

The card-sorting experiment has many possibilities. The author uses a card-sorting box having six rows of

trays with five trays in a row, thirty in all. These are numbered in miscellaneous order from 11 to 41. On the reverse side of the box there is the same number of trays. For the study of inhibition, these have the same numbers with a different arrangement. There are five cards of each number, 150 in all. In six days of practice not only can reliable measures of learning capacity be obtained but data be secured for the construction of six comparative learning curves, and facts be discovered which throw light on the problem of transfer of training. The procedure is as follows: On the first day of practice, the learners spend an hour sorting into the first row of boxes. Since there are only five boxes in the row, their location is soon learned and the learning curve rises fast. On the second day, the learners spend an hour on the second row of boxes. On the third day, they take the third row, and so continue to take a new row each day till all the rows are used. This requires six days if only one side of the box is used. By going on with different numbers, both sides of the box can be used, giving twelve days of learning with a new set of boxes for each day. Such an experiment teaches students more about habit-formation and the laws of learning than they could learn from a book in a long time. Indeed such facts can not be adequately learned from a book in any length of time. Facts discovered in this experiment which throw light on the problem of inhibition and also that of the transfer of training are discussed in later chapters.

The marble-sorting experiment, discussed in Chapter VIII, is a valid measure of capacity in motor learning. It has the advantage also of being different from the ordinary school work, and arouses great interest. It

requires a high degree of attention and concentration. It can be given to illiterates and young children. Subjects who have had much experience with the piano or typewriter have a slight advantage in the score. The author used this experiment with success in comparing the learning capacity of negro children with white children. The comparisons are shown in Table 26.

In the field of ideational learning the number of kinds of learning tests that can be devised is as great as the number of kinds of learning material. Nonsense syllables, properly constructed and arranged, furnish us with one of the best means of measuring learning capacity. Their learning demands a high degree of concentration. In a few hours several series can be learned, affording an adequate measure of this form of learning. The material has the advantage that it is absolutely new to experience. Previous experience gives no bias. The associations must be established *ab novo.*

It may be claimed that the best types of learning tests should use meaningful material. The author has some sympathy with this claim. Such material has many advantages, but has the disadvantage that when used for comparative purposes, it will favor certain subjects or groups of subjects, because of differences in previous experience and interest. If we take great care in the selection of test material, such tests as those usually given under the head of logical memory are of great value in measuring differences in learning capacity. There are various ways in which they can be administered. A description of two methods will be sufficient. A short story can be divided into ideational units for ease in grading the results. This story is read to the subjects *once.* They then make a written

TABLE 26.

THE LEARNING CAPACITY OF NEGRO CHILDREN.

The numbers in the table represent the percentages which the Negro scores were of the scores of white children for the various ages. Test used, marble-sorting experiment.

Ages	9	10	11	12	13	14	15	Av.
Girls	81	76	72	79	73	75	73	75.6
Boys	84	79	80	74	77	83	81	79.7

reproduction of the ideas. The number of ideas adequately reproduced is the score. The other method of giving the test is to read the story once, have a reproduction, then continue to read it and have it reproduced until *all* the ideas are reproduced. This procedure has been used by the author for individual tests, the reproductions being made orally. The former method requires much less time, and if repeated with four different kinds of material, gives a valid measure of learning capacity.

To summarise: Learning is connecting. Any test that measures the capacity of a subject to establish connections between two processes not before associated, is a valid measure of general learning capacity. In practice, we should use several different types of test. Each test should be repeated at least twice, and preferably four times. The results of the several tests should then be combined and taken as a measure of learning capacity. Any test of learning capacity that uses only one kind of material and is given but once can be only a rough measure of learning capacity. In ordinary practice, only group tests can be used. The author recommends the use of the substitution test, the second procedure mentioned above, repeated four times; card-sorting, an hour test with each of six boxes; the learning of four ten-syllable series of nonsense syllables; and four tests of logical memory. The combined

results are to be taken as the measure of general learning capacity.

Where to Make the Measure.—If our purpose is merely to measure the quickness of learning, we have but to set our subjects to work forming new bonds, let them work for a time, then measure the degree of perfection with which the bonds are formed. But how long should we let them work? If there are only a few bonds to form, and the subjects work for a considerable time, and we then determine the subjects' relative efficiencies in using the bonds, we are not measuring learning capacity at all, but the various individuals' capacities to do a certain thing. We should take our measure early in the practice period in order to measure learning capacity and not final capacity. We should take our measure while the learning curve is still rising steeply. How many minutes or hours should precede the application of our measure depends upon the number and complexity of the bonds. In the case of card-sorting, the efficiency attained with five boxes in an hour gives a good measure. With thirty boxes, a better measure would be had after a longer period. The only advantage of a longer period, however, is to offset minor errors that would unduly affect a shorter period. In general, the longer the period covered by any mental test, the more reliable the test. For example, in a test covering a minute, the various accidents that happen in getting started—accidents with paper, pencil, etc.—have an appreciable effect on the score. Such accidents do not have a measurable effect on a test covering an hour. In learning involving the formation of very many bonds, we should not apply the measure until all the bonds are formed at least weakly.

The importance of knowing when to apply our measure is at once apparent when we undertake to measure the learning capacity of people having widely different learning capacities, as negroes and whites. If we take the efficiency at the end of five minutes practice with a nine-digit substitution test, we find the whites very much superior. If we should take as our measure the efficiency attained by twenty minutes of practice, the negroes are found to be as good as the whites. In the first case we are really measuring learning capacity; in the second case, we are measuring not learning capacity at all but quickness at copying. At the latter task, the negroes are as good as the whites.

It is quite evident that at different points on the learning curve, we measure different things. We said above that in the case of card-sorting involving 30 boxes, we should not make our measure too early. The reason for this is that in such a case we are measuring neither learning capacity nor final efficiency, but how quickly a person can look over a list of numbers and find a certain one.

Correlations in Learning Experiments.—The various questions raised in the above discussions can be scientifically studied by applying the correlation formula. We can put a group of people to working at a learning experiment and allow them to continue till considerable fixation is reached, taking measures of efficiency at frequent intervals. We can then compare the relative standing of our subjects at any point with their standing at any other point. In nine-digit substitution, for example, in an experiment involving 29 subjects who worked for five-minute periods, the correlation of standing at the end of the first five minutes with that

at the end of five practice periods was .64, while the correlation of the standing at the end of the second period with that at the end of the fifth was .96. In a learning experiment so simple as this, the subjects very soon assume relative positions that are indicative of their final efficiencies. Even in a complicated learning experiment such as sorting cards into 30 boxes, a group of subjects soon reach a relative position that changes little. In the case mentioned, four subjects on the fourth day attain relative positions that do not change during the rest of the experiment.

Relation of Learning to Other Functions.—The relation of learning capacity to other mental functions and to general intelligence can be determined by correlating the results of learning tests with the results of other types of mental tests and with other measures of general intelligence, such as class standing or the estimates of teachers. In Table 27 are shown the correlations of three learning tests with the results obtained from the Army Alpha test.

TABLE 27.

LEARNING CACAPITY CORRELATED WITH GENERAL INTELLIGENCE AS DETERMINED BY THE ARMY ALPHA TEST.

Digit-symbol substitution with Army Alpha	.32
Marble-sorting with Army Alpha	.30
Card-sorting with Army Alpha	.25

If learning capacity is determined by combining the results of the substitution test, marble-sorting test, and card-sorting test, and the combined rating correlated with general intelligence as determined by seven group tests, the correlation is found to be .42. The group tests were tests of logical and rote memory, word-building, substitution, opposites, completion test,

analogies. The corresponding correlation obtained from a different group of students was .467. With this second group of students the substitution test alone gave a positive correlation of .42 with general intelligence; marble-sorting test, a correlation of .33; and nonsense-learning, a correlation of .46.

In a class of 40, class standing was determined by three examinations, general intelligence from the results of seven group tests mentioned above and learning capacity by the three learning tests—marble-sorting, card-sorting, and digit-symbol substitution. The following correlations were obtained:

Class standing with	
Average of mental tests gives	.41
Average of learning tests	.436
Logical memory alone	.22
Completion alone	.29

The high diagnostic value of learning tests is at once evident. If learning capacity could be determined with absolute accuracy and class standing determined with equal accuracy, the correlation between the two would probably not be over .50 or .60, because of the many other factors that enter into the determination of class standing. Learning capacity is probably the most important single factor, but previous preparation for the course, interest in the course, amount of time spent in study upon the course are important factors in determining class standing.

In conclusion it may be said that general learning capacity can be determined by the use of several forms of learning tests, and that the results of such tests are valid in practical diagnosis.

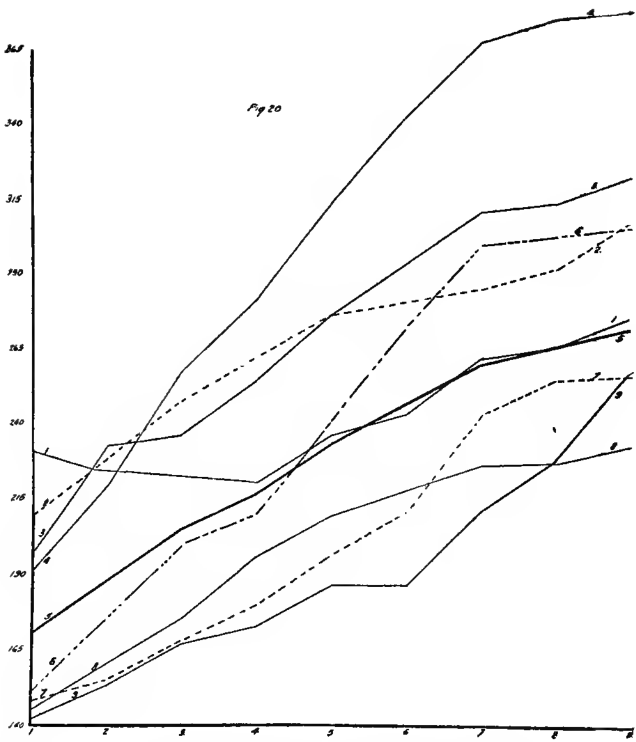

FIGURE 20. LEARNING CURVES, DIGIT-LETTER SUSTITUTION. The group average is shown by the heavy line 5, the other lines show individual records. After the first few practices, the individuals maintain their relative ranks with considerable constancy. However, number 6 starts below the average and finishes above the average, and number 1 starts highest and soon falls to near the average, finishing but little above.

The amount of regularity to be found in a practice experiment, and the relative ranks of the subjects at different periods of practice, are shown in Table 28. The experiment which furnished the data for this table was as follows: Thirteen subjects practiced at a substitution test, five minutes at a time, four times a day for three days. The results for each practice are converted to a group average of 50. This enables the reader to determine at a glance how each subject stood at any time with reference to the group average. It will be noticed that some subjects are always above the group average and others are always below, while some who are close to the average are sometimes a little above and at other times a little below. If the first two tests are combined and taken as a measure of initial speed, and the last two are similarly combined as a measure of final speed, and the two arrays correlated, the correlation is found to be .554. If all those subjects above the average are combined into one group and those below the average are combined into another group and graphs constructed to show their relative position above and below the average, we get the results shown in Fig. 21. It will be seen that the fast group as a whole is fast throughout, and the slow group as a whole is slow throughout.

The actual raw correlation of each practice period with the last is as follows: 1, .383; 2, .700; 3, .755; 4, .834; 5, .793; 6, .767; 7, .861; 8, .939; 9, .965; 10, .952; 11, .976.

In comparing learning capacity in one kind of material with that in another, it is of special importance that we know just where to apply our measure. If we apply it at a point where the curves are still steep, we

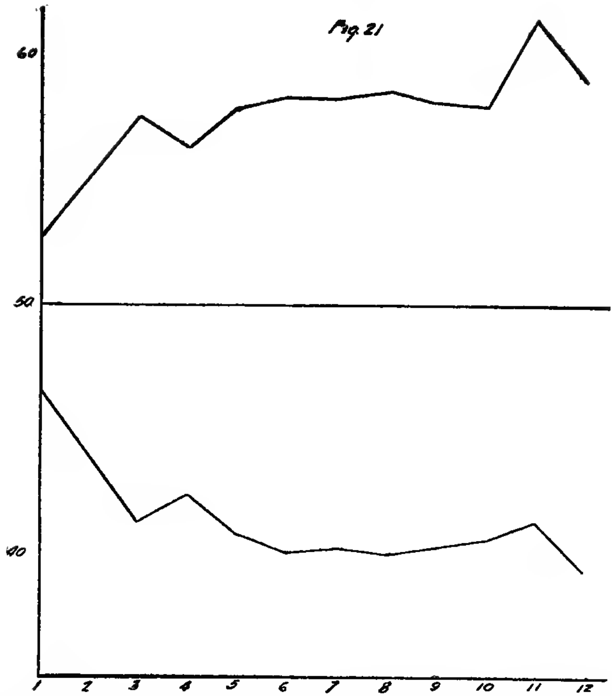

FIGURE 21. GRAPHS FOR SUBSTITUTION EXPERIMENT. The horizontal line shows the group average. The upper graph is the learning curve for those who averaged above the group average, and the lower curve is for those who were below the group average.

are really comparing learning efficiency. If we apply it after the curves have become relatively flat, we are comparing the efficiency of two different functions. In the latter case, the correlation might be high and positive or it might be high and negative.

An important question arises here. What is the relation of learning capacity to final efficiency? The question can be answered by correlating standing early

TABLE 28.

SUBSTITUTION EXPERIMENT. TWELVE PRACTICE PERIODS, THIRTEEN SUBJECTS, SCORES ALL REDUCED TO A GROUP AVERAGE OF 50.

The successive practices are shown from left to right.

Subject.	1	2	3	4	5	6	7	8	9	10	11	12	Av.	
A......	43	42	44	50	51	52	52	56	55	49	58	56	51	1
B......	46	54	45	52	37	40	47	47	50	52	61	57	49	— 1
C......	45	49	43	40	37	33	31	30	32	30	29	28	36	—14
D......	59	57	53	50	49	56	53	55	58	55	63	59	56	6
E......	59	52	59	52	57	61	57	57	58	57	61	56	57	7
F......	53	46	52	51	50	55	54	52	49	51	50	51	51	1
G......	46	31	33	41	43	44	40	42	43	42	42	44	41	— 9
H......	48	42	46	45	47	44	43	39	39	40	38	35	42	— 8
I......	69	69	64	62	61	50	55	60	65	70	68	66	63	13
J......	48	67	73	78	74	73	76	68	69	65	70	67	69	19
K......	44	39	38	33	40	41	40	40	36	39	35	32	38	—12
L......	38	53	58	53	64	62	61	62	53	59	61	59	57	
M......	51	47	42	43	40	38	40	41	42	40	43	40	43	— 7

in the learning curve with standing after the curve has become relatively flat. In all such computations made by the author, the correlations are found to be positive. As a rule, the quick learners have the highest final efficiency. It therefore turns out that although learning capacity and final efficiency are different things, they are positively related. In a group of learners there is not much change of position after practice has proceeded a little way. Of course there is some change of position due to the fact that the particular material may demand specific abilities that are not possessed in the same proportion as learning capacity, and also due to different methods used by the learners. In some cases an early score is low because of a method that does not give good results immediately, but later. In card-sorting, for example, a low early score may be due to the fact that the subject is trying to fix the location of boxes in mind. A valid measure of learning should be taken late enough for such slow learning to show

its effects, perhaps at a point where the curve is most convex. In general ,then, the learners who stand high early in the practice periods, stand high later. This is shown in Fig. 20, page 187. It will be noticed that those who are high early are high at the end of a practice.

Hollingworth has made a study of the effects of practice on correlations, but his study did not involve learning capacity in the sense that we are using it. He studied the following functions: adding, opposites, color-naming, discrimination, cancellation, co-ordination, and tapping. The correlation in the preliminary test was .41. In the 5th, 25th, 50th, 80th, 130th, and 175th practices, the average correlations of each with all the others were respectively .61, .73, .77, .85, .92, and 1.00. This increase in the correlation is due to the stabilizing of the performances. After 175 practices each of these tests measured the same thing, namely reaction time. In any kind of motor performance, final efficiency depends upon reaction time. In the case of learning experiments the author has often found a higher correlation between early practices than between later ones. In studying correlations, therefore, we should always bear in mind what the things are which we are correlating. Burt finds a higher correlation with intelligence before than after practice in the case of mental tests. This is because intelligence is more closely related to quickness of learning than to final efficiency, although all three are generally in some degree positively related.

EXPERIMENTS AND EXERCISES.

1. The learning capacity of the members of the class may be determined by combining the results of all the learning experiments so far used in the course. Others

can be given as described in this chapter. In combining the results, the class averages in each test should be reduced to 50 and all the scores expressed in relation to this average. The scores should then be added and divided by the number of tests. All students whose combined score average is above 50 are of course above the class average, those below 50 are below the class average.

For references, see page 173.

CHAPTER X.

DIFFERENCES IN LEARNING CAPACITY.

Individual Differences.—When we measure the learning capacity of a group of students, we find great individual differences. In Figure 22 is shown the distribution of 443 university students with reference to their learning capacity. The test used was the substitution test. The subjects were all students in the same course in educational psychology in successive classes. Men and women are included together in the records shown in the figure. There were about one-fifth as many men as women. Efficiency is indicated by the scores shown on the horizontal axis. The efficiency scores range from 28 to 72. The average of all the scores is 50. The peaks just above and just below 50 are probably due to our combining both sexes in the same curve, for the women average ten per cent. better in learning capacity, as shown by this test, than the men.

A child's status in school is determined chiefly by his general intellectual ability, but learning capacity is doubtless the main factor in intellectual ability. The variability in learning capacity is well shown in Figures 23 and 24. In Fig. 23 is shown the age distribution of 2943 boys and 3152 girls in the eighth grade of the Detroit schools. It will be seen that eighth grade children range in age from 10 to 17. In Fig. 24 difference in ability is shown in a different way. The graphs show the grade distribution of all the eleven-year old children

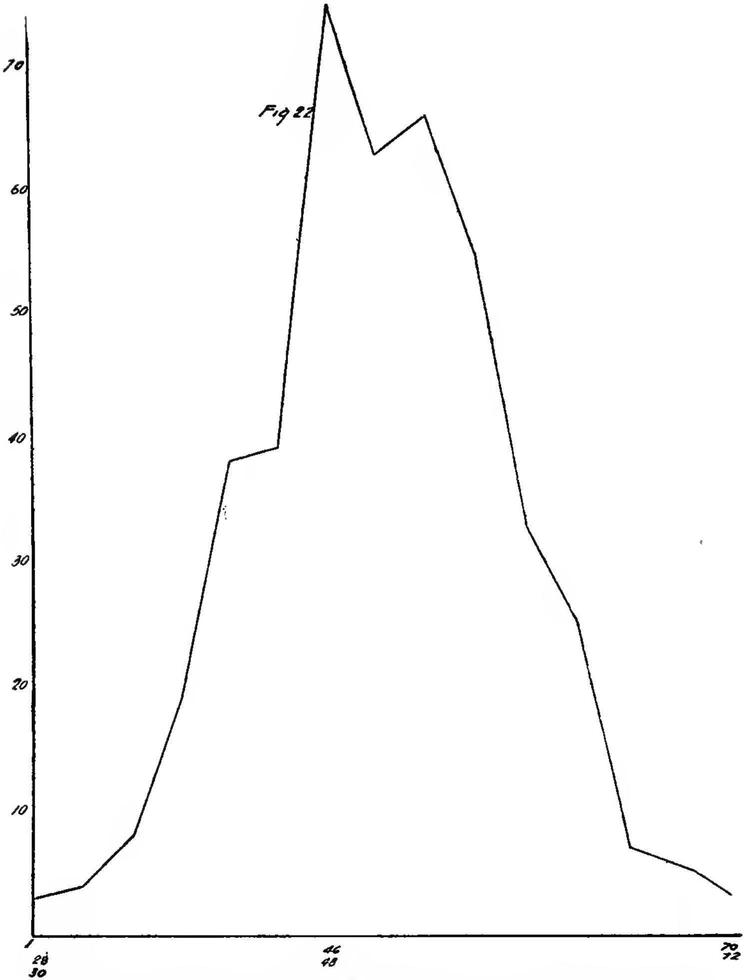

FIGURE 22. FREQUENCY SURFACE showing the distribution of 443 university students with reference to their learning capacity as determined by the substitution test.

in the city of Detroit. It will be seen that they range from the first grade to the ninth. The graphs represent 2382 boys and 2457 girls.

Collings found the distribution of 112 twelve-year old boys in the rural schools of a certain county to be as shown in Table 29. The author studied experimentally the mental differences of forty-four twelve-year old pupils in the schools of a certain small city of Missouri. Their distribution through the grades and their mentality as shown by four tests are given in Table 30.

TABLE 29.

SHOWING THE GRADE DISTRIBUTION OF 112 RURAL BOYS.

Grade.	1	2	3	4	5	3	7	8
Number pupils	4	4	14	17	39	13	18	3

TABLE 30.

SHOWING THE DIFFERENCES IN ABILITY OF 44 12-YEAR-OLD PUPILS.

School Grade.	Number Pupils.	Completion Test.	Logical Memory.	Word Building.	Opposites,
4	4	17.8	22.2	3.5	2.5
5	10	41.6	33.0	8.5	6.4
6	23	50.4	34.2	6.6	7.9
7	7	59.9	42.5	7.5	9.4

In four different high schools, the author selected the brightest and the dullest pupils on the basis of class standing and teachers' judgments, and determined their general ability by means of various tests. The tests were somewhat different in different schools. The results of all these studies are shown in Table 31. The figures, expressed in per cents, in every case indicate the amounts by which the good pupils excelled the poor ones.

The scores of the bright pupils are, on the average, about 21% better than those of the dull pupils.

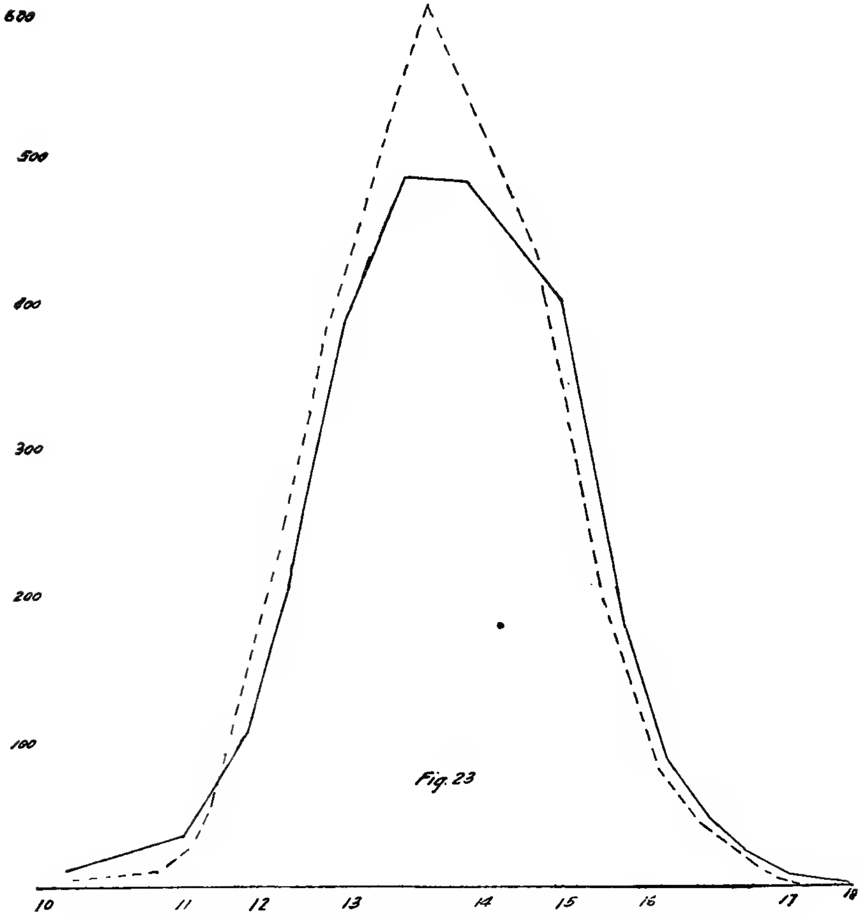

FIGURE 23. FREQUENCY SURFACES, solid line, boys; broken line, girls; showing the distribution of eighth grade children in the city of Detroit with reference to age; 2943 boys; 3152 girls.

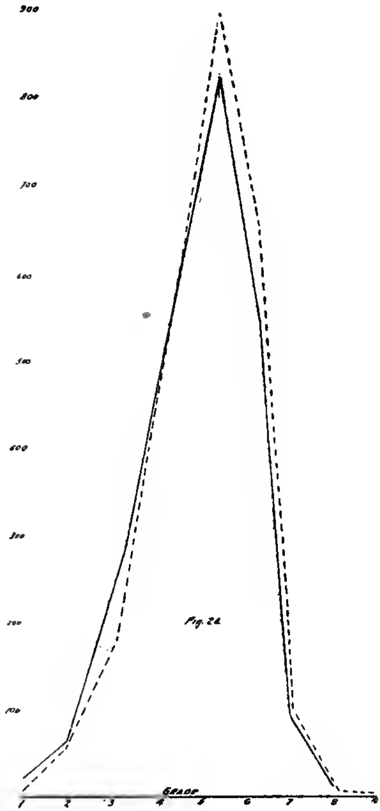

FIGURE 24. FREQUENCY SURFACES showing the distribution of eleven year old children, city of Detroit, with reference to grade, solid line boys, broken line girls; 2382 boys, 2457 girls.

TABLE 31.
SHOWING THE AMOUNTS—EXPRESSED IN PER CENTS.—BY WHICH BRIGHT PUPILS EXCELLED DULL ONES.

School.	Logical Memory.	Rote Memory.	Word Building.	Completion.	Substitution.	Controlled Association.
A	23	......	36	39	13	24
B	23	15.0	28	25	11	8
C	.....	......	.....	23	28	13
D	33	2.4	18	.....	17	28
Average...	26	8.7	27	29	17	18

The variation in ability in learning capacity in the case of university men and women is shown in Figure 25. The type of learning was marble-sorting. There were 213 women and 127 men. It will be seen that the range of ability is about 1 to 5. Still another compari-

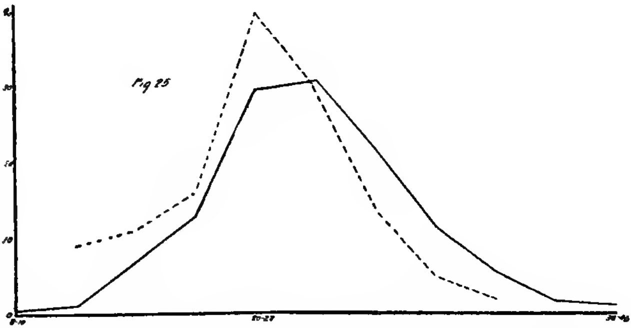

FIGURE 25. FREQUENCY SURFACES showing the distribution of university men and women with reference to learning capacity as determined by a marble sorting experiment. Solid line represents women and the broken line, men.

son of university students is shown in Figure 18. The test was the immediate reproduction of a story read to the subjects, who were 516 university women and 277 university men. In order that the surfaces might show

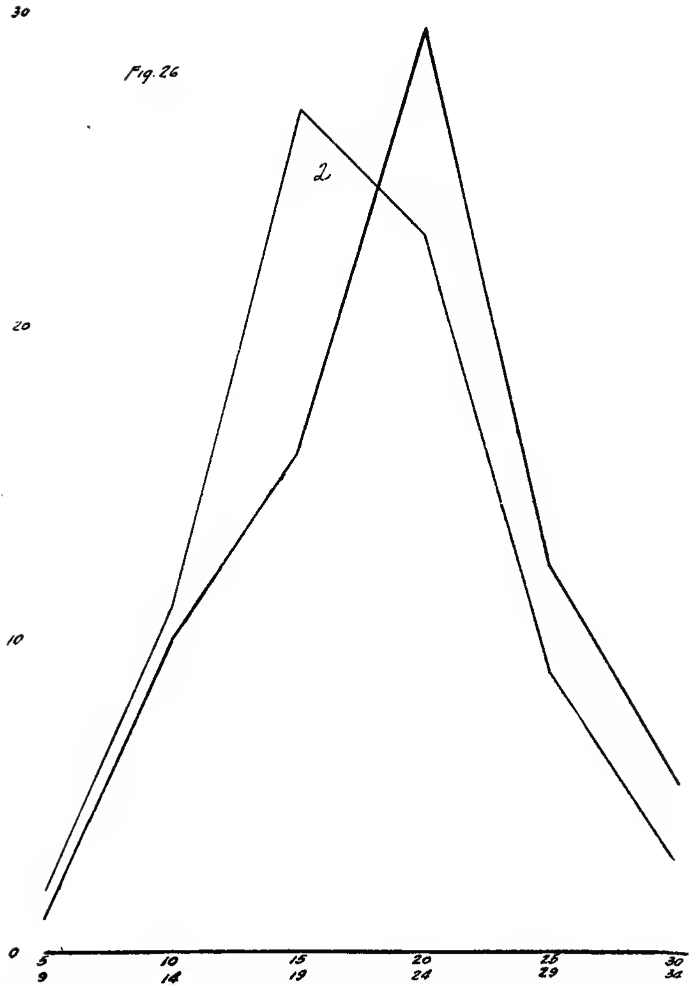

FIGURE 26. FREQUENCY SURFACES showing the distribution of all the children in a school with reference to learning capacity as determined by a substitution test. 1 represents girls, and 2 represents boys.

the same area, the number of men was multiplied by the ratio 1.86. In this experiment, the ratio of the poorest to the best is about 1 to 9.

The distribution of the pupils of an entire school system on the basis of learning capacity (Webster Groves, Mo.) is shown in Figure 26. These frequency surfaces represent all the pupils of both sexes and in all grades. In Figure 27 are shown the very great differences in ability found in the same grade. The curves in this figure are based on mental measurements. The subjects are the pupils in a small school system. It will be noticed that the range within a grade is very great and that the grades overlap. A large number of pupils in the fifth grade, for example, have no better ability than many in the fourth.

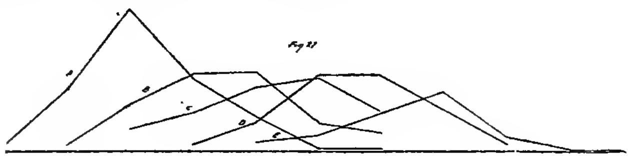

FIGURE 27. These graphs show the range of ability in the same grade and the overlapping of grades. Ability was determined by seven group tests. The pupils were all the children in the grades indicated, in the schools of Webster Groves, Mo.

Definite differences in capacity are forcibly shown in Figure 28. The graphs were constructed as follows: Four subjects sorted cards one hour daily for 15 days. After several days they sorted seven times in one hour. The average of each sorting for all the days was taken for each person and from these averages, the graphs were constructed. The records for the graphs are in the form of number of seconds required to sort 150 cards. It is evident that these four subjects are definite

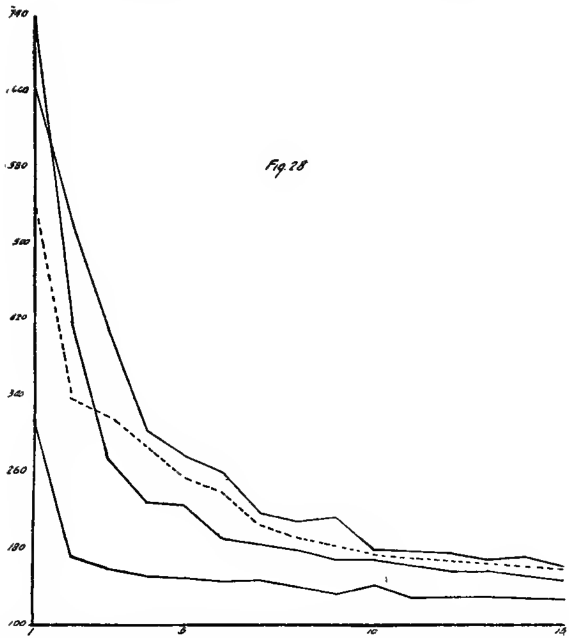

FIGURE 28. LEARNING CURVES, four subjects, card-sorting. The scores are the number of seconds required to sort 150 cards.

and distinct in their several abilities in mastering card-sorting and in sorting them after the various habits were formed. It will be seen that on the third day, the subjects assumed relative positions that did not afterward change.

Learning Capacity of Country Children.—A comparison of the learning capacity of country children with that of city children is shown in the following Table. The children studied were all the pupils in the country schools of a certain Missouri county. The city norms with which they are compared were obtained by giving

the same test—substitution—to the children of various Missouri cities. The test was the digit-symbol substitution test, and the scores shown in the tables represent the number of substitutions made per minute.

BOYS.

Age.	8	9	10	11	12	13	14	15	16	17	18
City	7.9	10.0	11.8	13.4	15.4	16.8	19.2	22.1	23.7	26.4	24.4
Country	6.0	7.7	9.2	12.4	14.6	17.3	19.8	20.5	21.2	22.4	25.5

GIRLS.

Age.	8	9	10	11	12	13	14	15	16	17	18
City	9.1	10.8	13.8	15.8	18.2	20.3	22.2	24.1	26.9	28.1	28.3
Country	7.1	8.4	11.9	15.2	19.8	21.9	23.5	24.8	27.6	28.6	28.3

In Figure 29 city and country children are compared with reference to their standing in several mental tests, substitution, as shown in the above, and also, logical memory, rote memory, association, and completion. The figure is constructed as follows: The horizontal line at the top represents the standing of city children. The graphs of the country boys and girls are drawn so as to show the percentage of the city scores which the country boys and girls make at the different ages. As the children grow older there appears less and less difference between city and country. It will be seen that the country pupils make only about 60% as high a score at age 8 as do the city children.

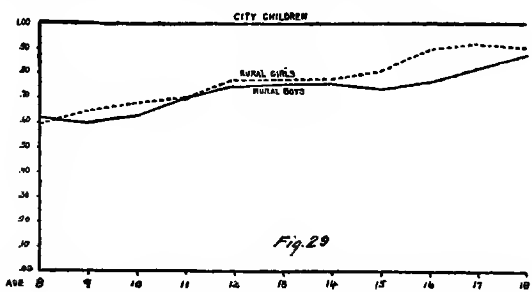

FIGURE 29. The graphs show the mental ability of country boys and girls as compared with city children.

Racial Differences in Learning Capacity.—Careful, though not extensive, studies have been made of the learning capacity of the American Negroes and of the native Chinese. In Table 32 Chinese boys and girls are compared with American boys and girls. The numbers in the table represent the per cent. which the Chinese scores are of the American scores for the ages shown. In the substitution test alone, the average efficiency of the Chinese children is, in the case of boys, 86.6 per cent. of American learning efficiency, and, in the case of girls, 77.9 per cent. If the results of the various tests are combined, it is seen that the average efficiency of the Chinese is for boys, 84 per cent. and for girls, 77 per cent. of that of Americans. In Table 33 a similar comparison is made with the Negroes. The average of the norms for the Negro boys is 57 per cent. of the average for whites. The average for the Negro girls is 60 per cent. of the average for white girls. In the substitution test alone, the average score for the Negro boys is 44.5 per cent. of the white average. The average for Negro girls is 43.7 per cent. of the average for white girls.

It will be seen that the Chinese, although they were at many disadvantages in experience, training, and language, compare very favorably with American white children, while the Negroes, although at no such disadvantage, show up very poorly.

The author made an extensive study of Negro ability to learn, using for the purpose the marble-sorting apparatus mentioned above. The comparisons are shown in Figures 30 and 31.

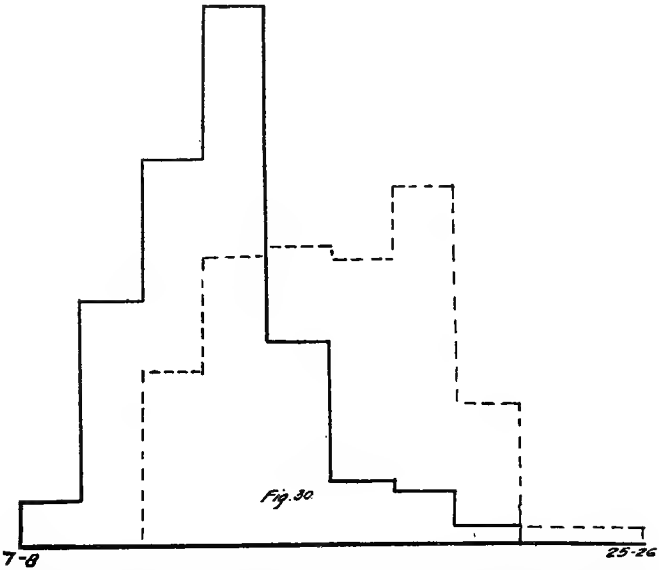

FIGURE 30. FREQUENCY SURFACES showing the distribution of white children and negro children in ability to learn as determined by the marble-sorting experiment. Solid line represents negro children; broken line, white children.

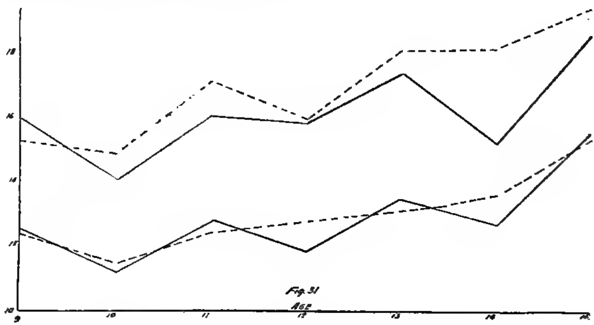

FIGURE 31. Graphs showing the learning capacity of negroes and whites, ages nine to fifteen; upper graphs represent whites; lower graphs, negroes; broken lines, girls; solid lines, boys.

TABLE 32.

A PER CENT. COMPARISON OF CHINESE WITH AMERICAN CHILDREN.

	Age.	12	13	14	15	16	17	Av.
Rote memory	Boys	125	118	122	116	122	109	117.0
....	Girls	122	114	103	102	97	112	108.3
Logical memory	Boys	82.2	77.3	85.2	89.1	90.1	99.6	87.3
	Girls	97.9	96.7	89.6	93.5	94.9	95.3	94.7
Substitution	Boys	91.3	85.6	93.0	81.8	83.4	96.6	88.6
	Girls	85.2	83.8	75.4	77.2	66.5	79.5	77.9
Analogies	Boys	23.1	33.1	42.5	39.1	40.4	37.8	36.0
	Girls	85.2	83.8	75.4	77.2	66.5	79.5	77.9
Spot pattern	Boys	116.0	100.0	80.6	65.2	98.1	82.4	90.4
Average	Boys	87.5	82.8	84.7	78.2	86.0	85.1	84.0
	Girls	81.7	84.1	73.6	74.3	69.5	78.6	77.0

TABLE 33.

The numbers in the table show the percentage which Negro ability is of the ability of white children:

GIRLS.										
Ages	8	9	10	11	12	13	14	15	16	Av.
Logical memory, immediate	68	79	74	85	68	76	92	88	72	78.6
Logical memory, delayed	90	88	52	86	51	76	68	115	81	79.6
Rote memory, concrete	55	76	59	87	76	85	97	95	110	83.0
Rote memory, abstract	44	61	45	56	66	69	84	79	96	69.8
Substitution digit-symbol	12	36	23	38	29	50	60	48	67	43.7
Opposites	25	47	80	55	46	55	60	63	68	53.7
Genus-species	18	31	13	28	28	42	49	43	47	36.5
Part-whole	21	47	28	43	49	53	61	50	45	46.6
Word building	42	62	45	75	31	52	66	24	46	49.1
BOYS.										
Logical memory, immediate	90	75	58	86	82	74	102	92	84	82.5
Logical memory, delayed	65	82	95	93	107	84	89	100	76	87.7
Rote memory, concrete	57	69	58	60	74	79	86	104	102	76.5
Rote memory, abseract	34	36	42	45	62	64	67	94	96	62.7
Stubtstition digit-symbol	18	27	28	36	32	35	53	63	68	44.5
Opposites	17	21	21	37	46	47	48	64	61	44.6
Genus-species	17	16	16	23	28	21	27	32	34	25.3
Part-whole	25	33	26	32	32	45	54	50	47	41.5
Word building	7.5	50	66	48	45	50	21	51	77	48.1

When Negro children are compared with white children with reference to learning capacity alone, it is found that only about seven and one-half per cent. reach the median for whites, while ninety-two and one-half per cent. of the whites exceed the Negro median. In general mentality as shown in Table 33 about one-fifth of the Negroes are equal or superior to the average of the whites. Three fourths of the whites are equal or superior to the average of the Negroes.

Causes of Individual Differences.—The causes of individual differences in learning capacity may be grouped under two heads, (1) hereditary and (2) environmental. The great influence of hereditary factors is shown by such studies as Galton's study of twins, Thorndike's study of twins, Goddard's study of the causes of feeble-mindedness, Galton's studies of hereditary genius, and by various studies of learning capacity.

Galton found that twins that were alike remained alike in spite of difference in treatment, and that twins that were unlike remained unlike in spite of similarity of treatment. Thorndike found the resemblance among twins to be greater than the resemblance among siblings. Goddard's extensive studies of feeble-mindedness show heredity to be the chief cause of mental defect. In fact, Goddard's figures seem to show that feeble-mindedness is Mendelian and recessive. In Galton's studies, although there is always the queston as to the part played by favorable family influences and training, there seems no question of the preponderant influence of heredity. In learning experiments, it is found that practice does not eliminate differences. In some cases, practice decreases, somewhat, individual differences, but in no case does it eliminate them. All careful experiments in learning show not only that ability to learn is a definite characteristic, but that final efficiency at any performance is definitely dependent upon native, inherent factors, that seem as definite and characteristic as are a person's height and weight, or any other physical features. When a group of subjects are started on a learning experiment, after a short time, they assume characteristic, definite,

relative positions, that remain constant except for minor fluctuations, which are due to temporary causes.

In the public schools, it is found that children early in the grades assume a position in ability with reference to their fellows which remains fairly constant in the later grades. For a pupil to be poor in one grade and good in a later grade is the exception, and probably has some clear explanation other than native ability. As a rule, bright children continue to be bright and dull children continue to be dull in spite of what may happen to them. Special attention has now been given to subnormal children for many years. It is found that even when they are taken early and given the best training that science is able to give, they remain subnormal in as true a sense as they retain their hair-color or their facial features.

One of the strongest arguments for the influence of hereditary factors comes from a theoretical consideration. Biological studies in heredity show that the structure of living tissues is dependent upon hereditary forces. The brain in its structural aspects falls within the general category of causality, is a product of heredity. The differences in the nervous development of different classes and species of animals are clearly hereditary, so also are the smaller differences within the human race. No one would probably deny that the tremendous difference between the idiot and the genius is due primarily to differences in brain structure. There seems no doubt that smaller mental differences are also due chiefly to differences in hereditary brain structure.

An important fact pointing to the influence of heredity comes from studies concerned with training in

mental functions. It seems that training has no very great influence on simple functions, such as reaction time, mental span, speed of association, sensory discrimination. The ordinary experiences of life bring these and other simple mental functions to approximately their full possibilities. Much improvement is possible in the case of complex mental functions, but such improvements are not due to fundamental changes in native ability but to tricks and schemes of method and procedure; in most cases they are due to the establishing and perfection of some bond or other.

Environmental Influences.—The relative importance of heredity and environment in the life of an individual is a question that has been much discussed, and on which people have very different opinions. There is really no room for difference of opinion. An appeal to the facts shows that heredity and environment are complementary, that each makes its own contribution, and which the other can not make. The bodies that we have, with their bones and muscles and nerves, come from our ancestors; they are the gift of the past. We are tall or short, heavy or thin, light or dark, because of heredity. Our nervous systems on which all educational influences must work, are the gifts of heredity. The value and efficiencies of these nervous systems range all the way from near zero to those having almost infinite possibilities. Heredity gives us the raw material on which educational influences work. This raw material has its possibilities and its limitations. Education cannot transcend these limitations. But while social influences are limited to the material which heredity gives, they are of very great importance. What this importance is, we must now see.

The statistical studies of Cattell show well the importance of environment. He found that the Southern states have contributed very few men of science as compared to the New England states. The man of the South is very much the same sort of man as his brother of the North. He does not go into science because the influences do not urge him in that direction. He becomes a land owner, a man of affairs. In New England are our greatest universities. The influences there are such as to invite to an educational career, to science, to letters. Nature determines what is possible for us to do. The kind of work in which we actually engage is largely determined by the influences which surround us.

The relative importance of heredity and environment is well illustrated by musical ability. Suppose that somewhere in the "backwoods" of the mountains a child is born having in it the possibilities of a great pianist. If the circumstances of life are such that this child never even sees a piano, he will never become a pianist. On the other hand, there are children who can never become great pianists, although all the influences of wealth and science combine to make them. The fact is that heredity and environment combine and give us the outcome of every life. Every act of our lives is the resultant of what we are and of the influences that work upon us. The same influences do not get the same result from different people because the people are different. If you lay side by side on an anvil, a piece of glass and a piece of iron and strike them both with equal force, the glass is crumbled to bits, the iron is scarcely dented. The forces that act upon them are the same, *but the things are different.* So it is with people. The same influences that save one boy to good-

ness and usefulness sometimes fail to save others, *because the others are different* and do not give the same response to the same stimulus. In the same school room the same educational influences work upon all the pupils, but *some learn fast and others slowly.* But what we must not lose sight of is that each can *learn something.* Education can make each different from what he would otherwise have been. It can not make them all alike, it can not make them equally efficient, but it can make each more efficient than he would otherwise have been. It is well that we recognise the truth; it is well that we know the facts and face them squarely. Social reformers often make the mistake of assuming that the same causes will always produce the same effect. The same effect is produced only when the same causes act upon the same or equal things. And nothing in the world is more unequal than human beings. On the one hand, we have the idiot that can scarcely be taught to feed itself; on the other, is a Newton, or a Shakespeare.

The School and Individual Differences.—Both scientific studies and common observation show us that there are great individual differences in learning capacity. The practical question is: What are we to do about it? The school can not ignore them. It must take them into account. By means of scientific measurements and on the basis of actual achievements in the school, the children should be divided into classes according to their ability to learn. A child should be put into a class with other children having about the same ability. When this is done, it is possible for us to do what is best for each child. Some can go fast; others more slowly. Not only will the different groups have differ-

ent learning capacity, but they should learn, to some extent, different things, in preparation for filling widely different places in the world. The distinctly sub-normal children should have a very different course from that pursued by the great majority of normal children. To make this possible, they should be separated from the other children. Their education should be almost wholly manual. The unusually bright children should also be put into classes by themselves to make it possible for us to do the right thing for them. They are to be the leaders of the coming generation. In every case, we are to do for each child what is best for each. The dull child has its claim upon us as well as does the bright. We put them into different classes only to enable us to do what is best for them.

EXPERIMENTS AND EXERCISES.

1. All the experiments so far performed may be used to show individual differences. Frequency surfaces can be plotted for each learning test, and for the combined scores worked out in the exercises of the preceding chapter. What is the range between the best and poorest in the several tests? In the combined results?

REFERENCES.

Bonser, F. G., *The selective significance of reasoning ability tests*, J. E. P., VII, 1916, 187.

Brown, W., *Some experimental results in the correlation of mental abilities*, B. J. P., III, 1910, 296.

Mental Measurement, 1911.

Dashiell, J. F., *The effects of practice upon two mental tests*, J. E. P., XI, 1920, 151.

Donovan, M. E. and Thorndike, E. L., *Improvement in a practice experiment under school conditions*, A. J. P., XXIV, 1913, 426.

Gray, C. T., *A comparison of two types of learning by means of a substitution test*, J. E. P., IX, 1918, 143.

King, I. and Homan, T. B., *Logical memory and school grades*, J. E. P., IX, 1918, 262.

McCall, W. A., *Correlation of some psychological and educational measurements*, 1916.

Pyle, W. H., and Collings, P. E., *The mental and physical development of rural children*. S. and S. VIII, 1918, 534.

Pyle. W. H.. *A study of the mental and physical characteristics of the Chinese*, S. and S., VIII, 1918, 264.

The mentality of negro children S. and S. 1915, p. 357. Psych. Bul. XIII, 1916, 82.

Simpson, B. R., *Correlations of mental abilities*, 1912.

Stickland, G. I., *The influence of practice on the correlation of abilities*, J. E. P., IX, 1918, 393.

Race, H. V., *A study of a class of children of superior intelligence*, J. E. P., IX, 1918, 91.

Strong, E. K., *An interesting sex difference*, Ped. Sem., XXII, 1915, 521.

Wells, F. L. and Henmon, V. A. C., *Concerning individual differences in reaction time*, P. R., XXI, 1914, 153.

Wells, F. L., *The relation of practice to individual differences*, A. J. P., XXIII, 1912, 75.

Whitley, M. T., *An impirical study of certain tests for individual differences*, Arch. of Psych., No. 19, 1911.

Wyatt, S., *The quantitative investigation of higher mental processes*, B. J. P., VI, 1913, 109.

Whipple, G. M., *Classes for gifted children*, 1919.

CHAPTER XI.

TRANSFERENCE AND INTERFERENCE.

Nature of the Problem.—The problem of this chapter may be stated in the following words: Will the formation of one habit either help or hinder in the formation of another? Will the acquiring of one bit of knowledge help or hinder in acquiring other knowledge? If I have learned to operate a typewriter having a certain keyboard will it be either easier or more difficult to learn to operate a typewriter having a different keybord? If one has learned to run an automobile will it be either easier or more difficult to learn to run a machine which has different types of levers and pedals? In the field of knowledge, does the learning of one language make the learning of a different language easier? Will the study of history make the acquisition of mathemathics easier? In general, are the results of learning narrow and specific, or, are there general effects also?

The problem raised here is of far-reaching theoretical and practical significance. It involves the very foundation principles of education, and we must face it at every turn in practice. It involves our fundamental conception of the nature of mind. Is the mind an entity, a unity, of such a nature that it gains strength by exercise? If so, then the effects of all learning are general, and it will make little if any difference what the mind does, for whatever it does gives it strength to do other things. One can train the muscles of his arms by one

sort of exercise and his arms will then have strength to do other things. I can strengthen my arms by chopping and they will have strenght for hoeing. Can I likewise train my mind by studying mathematics so that it will then have power to work in other fields? Our answer to these questions will color our whole scheme of education. If the results of training are specific, then we should learn those things which we most need to know, without any reference to their general effects. If the results of training are general, then we should pick out as the studies for our curriculum those branches which are best for the exercise of the mind.

Much of the misconception and misunderstanding with reference to this problem have been due to a misconception of the nature of mind. Modern psychology does not look upon the mind as an entity that functions as a unity and that can gain strength as a whole in the same sense that is true of a muscle. Mind is a complex, mosaic, of sensation, perception, idea, feeling, and depends in every process upon an almost infinitely complicated nervous structure. Modern conceptions of the nature of learning also put a different aspect on the problem. In the case of habit-formation, we couple a muscular response to a sensory stimulus. In the case of ideational learning, very definite brain processes which underlie the ideas are coupled together. Whether the formation of one such bond has any facilitating or inhibiting effect on the formation of another is an experimental question which can not be answered on *a priori* grounds. Let us turn to the experiments.

Historical and Critical.—Experimentation in this field lies almost wholly in the last twenty years. One would think that in twenty years a question so simple

and straightforward as this could have been definitely settled. But such is not the case. It is not definitely settled. There is not agreement among psychologists themselves, not to mention those who have no scientific knowledge of the question. There has been much experimentation. The literature is large. But very few experiments have been done with sufficient thoroughness and attention to scientific detail to merit the respect of an impartial investigator. As one reads the experimental literature, one seldom feels, with reference to any experiment, that it is final, that it settles that aspect of the question with which it deals. Few experimenters have repeated their experiments again and again, to see if every result confirmed every other. Too often the article reporting the experiments is only a "preliminary report." One usually searches the literature in vain to find a "full report" of the "main study." In more than one case, an experimenter has reported his results and given his inferences, while another psychologist would claim that different inferences were warranted from the results. Thorndike's inferences have been so questioned by Judd; Winch's, by Sleight. If educational psychologists are to command the respect of a scientific world, they must do their work with such thoroughness that it will stand the tests of repetition and criticism. Too often a class experiment that is scarcely worth anything as a mere demonstration is published as having scientific value.

A Statement of Method.—Before reviewing the experimental literature it will be well to make some enquiry as to the type of experiment required in solving our problem. We must take a group of subjects and have them form a habit which we shall call "X," and

then have them form another habit, "Y," and determine whether the formation of "Y" was easier because of their having previously formed habit "X." But how are we to know whether the second habit is easier of formation than the first? The only way we can be sure of this point is to have a second group form the second habit. The only difference between the groups must be that one has formed habit "X," and the other has not. Both are to form the second habit; only one is to form the first. The groups must be equal in every other respect; or, if not equal, the differences must be accounted for. Of course, if there is any way of comparing the difficulty of the two habits, the control group is not necessary. If, for example, we know that two habits are of equal difficulty, then we can have our subjects form first one, then the other. If the second is formed more easily than the first, then we can say that the effects of the first are favorable in the formation of the second. In some cases, such procedure is permissible.

Much of the earlier experimentation is worthless because the experimenter used no control group. Some of the later experiments also suffer from this defect. Ebert and Meumann's extensive memory experiments are worthless because of the lack of a control group. These experimenters gave their subjects practice in one aspect of memorising, and found improvement in other aspects. Later, Dearborn repeated the experiments and found that the control group improved about as much as Meumann's group that had the practice. Further explanation will make the matter of method clear. Suppose there are ten aspects of memory, and we wish to learn whether training in aspect number 5

will improve all the other nine aspects. We take a group of people and measure all 10 aspects of memory; we then train the group in aspect number 5 until there is great improvement and then measure again in the other nine aspects. Suppose we find that there is improvement in all the other nine aspects; we can not say that it is due to the practice in number 5, because, for all we know to the contrary, the group might have made this improvement without the practice. It may be that if we give the ten tests and then wait a few weeks and give ten similar tests again, there will be considerable improvement. In fact, such is usually the case. We must, therefore, in an experiment of this kind, take two groups and give one group the initial and final tests and give the other group the same initial and final tests and the *special practice besides.* Then whatever differences in the final tests are not otherwise accounted for, may be considered to be due to the practice.

Evidence from Card-sorting.—A very simple experiment in card-sorting will serve to bring the problem of transfer clearly before us. Suppose we take a card-sorting apparatus which has on each side six rows of five boxes each, thirty boxes on each side, sixty in all. Suppose we learn a row a day until we have learned the 12 rows. Will the mastery of each succeeding row be easier because of our having learned the rows before? The answer is *yes.* The following record is typical: A subject spends six days with one side of the box. Each row has different numbers from the preceding rows. Each succeeding row is learned with greater ease. After waiting two weeks, the other side of the box is learned. This other side has the same numbering as the first side, but the numbers are differently arranged.

The average number of cards sorted per minute for the first six rows were 53, 60, 64, 67, 75, 79. For the next six rows, the records were 78, 80, 80, 84, 91, 90. These records would raise a very strong suspicion in any mind to the effect that learning to sort cards into a row of numbered boxes would make learning to sort into a row of boxes with different numbers *easier*. We wonder whether all subjects will behave as did this one. Such proves to be the case. The author has repeated the experiment with different subjects and different groups and in all cases it is found that *learning to sort cards into one row of numbered boxes makes learning to sort into another row with different numbers, easier.*

The experiment just described was repeated with a group of 47 students. The group, however, sorted for only five days, learning a new row each day. Ten sortings a day were made in each case. The average time in seconds for each of the five successive rows was as follows: 23.2, 20.5, 19.7, 18.7, 18.2. The average time for the fifth row was 27 per cent. less than for the first row. The single subject reported above reached an efficiency on the fifth day 41 per cent. better than was reached on the first day with the first row.

Still another card-sorting experiment was performed as follows: A group of four university students sorted cards for fifteen days, using one side of the box containing 30 compartments, then fifteen days using the other side of the box having the same number of compartments. The thirty boxes on one side had the same numbers as the boxes on the other side, but the arrangement of the numbers was different. In the sorting of the second period, therefore, the habits of the first period had to be broken up. In spite of the inhibition

from the first set of habits, on the fifth day of the second experiment, a speed was reached as great as that attained in fifteen days in the first part of the experiment. The results of this experiment are shown graphically in Figure 32.

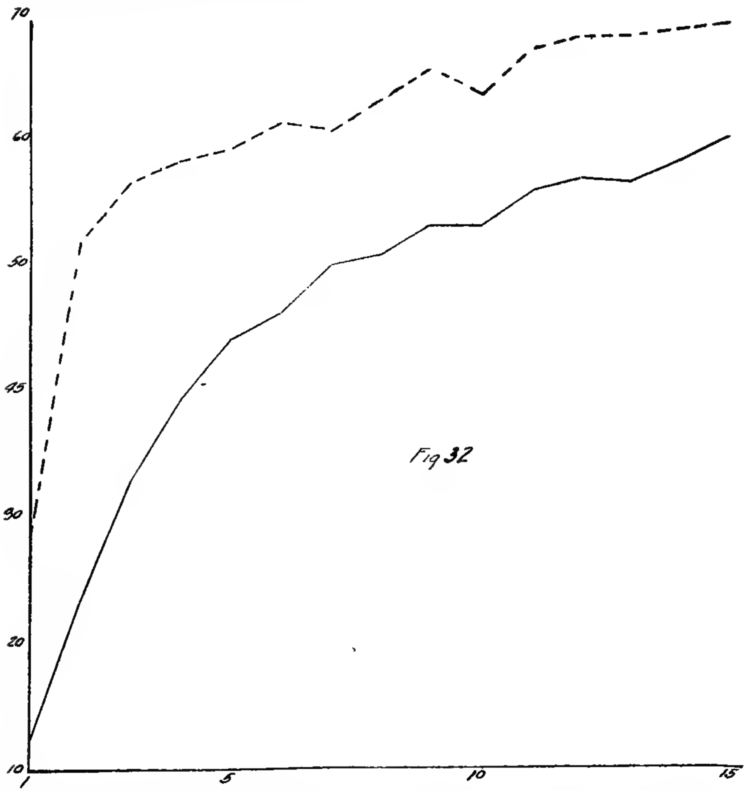

FIGURE 32. LEARNING CURVES, CARD-SORTING EXPERIMENT. The lower curve shows the results of fifteen days sorting with one scheme of numbering; the upper curve shows the results of a second sorting of fifteen days, with a different numbering of the boxes.

These simple experiments leave no doubt that the experience gained from sorting cards into one row of boxes makes it easier to learn to sort into another row of boxes having different numbers, or having the same numbers differently arranged. Two important questions now arise. (1) What are the causes of this improvement in ability to learn? (2) Does the improvement in ability to learn extend to other kinds of learning? The second question we shall leave for later discussion. The first question can be partially answered now. (1) Facility was gained in manipulating the cards. This increased facility improved the scores from day to day. Proof that increased facility is a factor comes from the following experiment: Two subjects were required to deal a set of playing cards into a compartment. The time became less from day to day. The records for the two subjects for 15 days were as follows:

Subject. Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A........	17.5	14.6	11.9	10.5	9.7	9.5	8.5	7.7	7.5	6.9	5.9	5.4	5.3	4.9	4.9
B........	20.0	15.8	16.2	15.0	13.2	12.9	10.3	8.8	9.2	7.7	6.3	5.2	5.0	5.9	5.9

The records are in terms of seconds required to deal out the 52 cards, all into the same compartment. It will be seen that the time required the 12th day was about 70 per cent. less than that required the first day. See figure 6, page 25.

(2) A second probable factor was increased ability to recognize the numbers of the cards. (3) A third factor was the learning of schemes by which the locations of numbers were associated and fixed. It is possible that subjects learn how to hold themselves to the task and resist distracting influences. One also learns how to hold the body, how to use the hands to best advantage,

how to get the cards out of the pack in the quickest way. All of these factors and probably others operate to reduce the time of learning the successive rows of boxes.

Other Similar Experiments.—Coover and Angell find that practice in card-sorting increases efficiency in typewriting. Bair's experiments are identical with the card-sorting experiments of the author's reported in the paragraphs above, except that he used the typewriter, requiring his subjects to master successive types of keyboard. He changed the keys from one experiment to another by putting caps on them. Six labeled keys constituted a series, and 20 series were learned. The average number of seconds required by four subjects for the first series was 73.4. For the twentieth series the time was 57.5, or 21 per cent. less.

Experiments in Memorising.—We shall pass over the early experiments of James and their repetition by Peterson without comment. As is well known, James took the position that memory in the sense of retention could not be improved. The most extensive experiments on the transfer of memory training have been performed by Fracker, Winch, and Sleight. The extensive experiments of Ebert and Meumann were repeated by Dearborn. As was mentioned above, Ebert and Meumann did not use a control group. Dearborn gave a group the initial and final tests to determine how much of the improvement which the German experimenters attributed to the practice was due to improvement from the initial to the final test. He found that the improvement of the final test over the first was about as much as the improvement of Ebert and Meumann's training group. In some cases, the improvement was more.

Fracker trained a group in memorising the order of four different intensities of the same tuning fork, and determined the spread of improvement to similar performances such as memory for four grays, and to dissimilar performances, such as memory for poetry, geometrical figures, etc. In the similar memorising, the improvement was 16 per cent. more than the control group. In the dissimilar memories, the improvement was only 3.75 per cent. more than the control group.

Winch performed two series of experiments on London school children. One group was trained in memorising poetry, and the transfer to memory for prose material in geography and history was determined. In one case the improvement was 10 per cent. more than the control group, and in another, 5 per cent. In a second series of experiments the training group was practiced in the rote memorising of meaningful and also of meaningless material. The transfer of the training to substance memory was determined. The transfer was very slight; the residual gain over the control group was about 3.3 per cent. on the initial ability.

The most extensive and careful experiments on the transfer of memory training are those of Sleight. He trained one group in memorising poetry, another in memorising tables, and another in memorising prose. He gave initial and final tests in many different aspects of memorising. His results show that training in one aspect of memorising gives little or no increased efficiency in other types of memorising. Sleight conducted two independent experiments, one with school children and one with two classes of women students 18 to 19 years old. The results obtained from the latter are shown in Table 34. The column to the left shows the

aspect of memory tested. Group 1 was the unpracticed group; group 2 was practiced in poetry; group 3, in learning tables; group 4, in learning the substance of prose. The figures indicate the improvement divided by the standard deviation. The practice covered a period of twelve days, one-half hour a day. A study of the table shows that there is no general improvement of memory. In nine cases the unpracticed group improved more in the aspects of memory tested than did the practiced group. In three cases the practiced group made a poorer record in the final tests than they had made in the initial tests.

TABLE 34.

Aspect of Memory Tested.	Group.	Gain.
Dates	Group 1 Unpracticed	3
	Group 2 Practiced in poetry	35
	Group 3 Practiced in tables	63
	Group 4 Practiced in prose substance	—1
Nonsense syllables	Group 1 Unpracticed	66
	Group 2 Poetry	100
	Group 3 Tables	75
	Group 4 Prose substance	4
Poetry	Group 1 Unpracticed	14
	Group 2 Poetry	47
	Group 3 Tables	—12
	Group 4 Prose substance	7
Prose, literal	Group 1 Unpracticed	35
	Group 2 Poetry	43
	Group 3 Tables	—1
	Group 4 Prose substance	18
Prose, substance	Group 1 Unpracticed	16
	Group 2 Poetry	8
	Group 3 Tables	65
	Group 4 Prose Substance	68
Letters	Group 1 Unpracticed	34
	Group 2 Poetry	9
	Group 3 Tables	30
	Group 4 Prose substance	7

A study of Table 34 shows that practice in learning poetry and tables gives facility in learning dates but

not in learning prose substance. Practice in learning poetry gives more facility in learning nonsense syllables, but very little more in learning tables than the unpracticed group gained, and not nearly so much gain in learning prose substance as was gained by the unpracticed group. These examples are sufficient to enable the reader to interpret the table.

Interpretation of Memory Experiments.—The memory experiments are essentially the same as the card-sorting experiments first discussed. In card-sorting, the subjects spent a certain period of time in fixing the association between a certain series of numbers and their corresponding boxes. They then built up another series of connections between other numbers and other boxes. We found that the first experience facilitated the later habit-formation. In the memory experiments, the subjects were given practice in building up the bonds necessary to enable them to recite, verbatim, poetry. It was found that this experience gave increased facility in learning dates and nonsense syllables, slightly increased facility in learning prose verbatim, but none in learning prose substance or in learning letters. Practice in learning tables gave increased facility in learning dates and prose substance, slight increase in learning nonsense syllables, but none in learning poetry or prose verbatim or letters. Practice in learning prose substance did not give increased facility in learning any of the other types of material. All the memory experiments are in substantial agreement. They show that experience in one type of learning may either facilitate or hinder another type.

Discriminative Judgments.—The experiments to be reported under this head are quite different from those

above discussed. They consisted in giving subjects practice in making a certain type of judgments, and then determining whether this practice facilitated or hindered the making of other types of judgements. In one type of experiment the judgment of experimenters is unanimous. In reaction experiments, practice in reacting to stimuli in one sense department gives facility in reaction to stimuli from other sense departments. Gilbert and Fracker, for example, found that simple and choice reactions to sound stimuli reduced the reaction time to touch and visual stimuli. He did not, however, use a control group. Coover and Angell did in similar experiments, and obtained a similar result.

Thorndike and Woodworth gave subjects practice in estimating various types of magnitude, such as lines, and surfaces, and weights. They found the effects of practice very narrow. Training in the estimation of the lengths of lines gave facility in estimating similar lengths but not in the case of lines very much longer or shorter. Judd however finds that practice in judgments of location of lines in one position facilitated similar judgments when the lines were in different positions, and that the influence of practice in making judgments concerning the Müller-Lyer illusion figure, was effective when judgments were made with the figure under different conditions. The situation with reference to this type of experiment is not so clear as in the case of the other experiments so far considered. There has not been sufficient repetition of experiments in the field of discriminative judgments to settle the question of the extent of transfer.

Experiments in Cross Education. — Experimenters are in agreement here. We need not go into a detailed

description of the experiments. A general statement will suffice. The most obvious fact here is that after we have learned to write with our right hand, we can write with some degree of legibility with the left hand. Further illustrations are as follows: Practice with the right hand in tapping improves the left. Practice in touch discrimination of one side increases the sensitivity on the other. Experiments with one eye in certain experiments with perspective are effective on the other eye. In general, practice which directly affects one side of the body has an indirect influence on the other side.

Transfer of Knowledge.—A few typical experiments will show the results of the transfer of knowledge to the mastery of a new situation. Judd tested subjects in shooting at a target under water. The subjects who knew the physical principle of refraction involved were able more readily to adjust themselves to a change in the depth of the target under water than was the case with those subjects who did not know this principle.

Hyde and Leuba found that practice in reading German script made the mastery of writing it somewhat easier, although this effect was limited. The author performed a similar experiment in card-sorting. If one subject sorts cards for two days, while another subject instead of sorting the first day, merely studies the location of the boxes and then sorts on the second day, the result is that the person who studied the first day makes a better score the next day than would have been the case without the study. However, the score is not so good as if the person instead of studying the first day, had begun at once to sort the cards. It is clear that knowledge helps in habit-formation, but nothing can fully take the place of direct, actual practice.

There have been many other experiments on transfer, that of Ruger with puzzles, and those of Bagley and Ruediger in neatness, as well as others which need not be described here. We have yet, however, to describe the most extensive experiment of all, most extensive in point of time and numbers involved.

Rugg's Experiment.—Rugg gave a group of 326 subjects a semester of training in descriptive geometry. He compared them with a control group of 87 subjects who did not have the training in descriptive geometry. The 326 subjects were freshman engineers. The control group was made up of 72 students in the school of education, and 15 in the college of engineering. It is unfortunate that the control group was not similar to the training group. The control and practice groups were given initial and final tests in non-geometrical material, quasi-geometrical material, and geometrical material. The non-geometrical material consisted in mental division, two tests, and in making words using the letters in the word M-A-T-E-R-I-A-L. The quasi-geometrical test was a test in straight-line lettering. There were two geometrical tests, one which Rugg calls the painted cube test and the other a test in imaging objects and determining how many lines would be necessary to construct them in space. The painted cube test was this: A three-inch cube is painted on all sides, how many one-inch cubes have paint on three sides? On two sides? On one side? On no side?

Results.—In one of the division tests, the practice group lacked .9 per cent. doing as well in the final experiment as did the control group. In the other division test, the residual gain of the practice group over the control group was 15.78 per cent. The average residual

gain in these two experiments was 7.44 per cent. In the word-building test, the residual gain of the practice group was 13.37 per cent. As this test was given, it was subject to direct influence from the practice in descriptive geometry. Holding the word and the letters in mind would be easier by virtue of the practice in visualising in descriptive geometry. The improvement in the quasi-geometrical test was 20.4 per cent.; while the improvement in geometrical material was 31.25 per cent. In each case, the gain is the residual gain over the control group. These, then, are the residual gains for the three types of test,—7.44 per cent., 20.4 per cent., and 31.25 per cent. Or, if we average the word-building test in with the two division tests, we have for the non-geometrical tests, a residual gain of 9.42 per cent.

This criticism should be passed on the experiment. While the division tests are non-geometrical, they are *mathematical* and the engineers would have more training in mathematical calculations during the semester than would the 72 education students. All the tests are too closely allied to the practice in descriptive geometry. Why did not Rugg test his two groups in something further removed from the practice, say in learning the English equivalents of Latin words or Chinese words. As the experiment stands, however, it falls in line with the other experiments already reported. *Some transfer is shown.* While Rugg tries to account for all the various factors that are likely to influence the results of his experiment, the impartial reader is likely to feel that the statistical method after all can not solve this particular problem. The ultimate solution will probably

come from extensive studies of a few subjects, with every factor under control or accounted for.

Starch and Hewins have also used regular school room studies in investigating the question of transfer. Starch uses eight students in his practice group and seven in the control group. He gave the former 14 days practice in mental multiplication and determined the effect of the practice on other mathematical operations and on immediate memory span. The drill group made a residual gain of 29 per cent. in the arithmetical operations but practically no gain in immediate memory span.

Summary of the Evidence.—We have now reviewed the results of the more important studies. We have not discussed several of the minor studies, but reference to all is made in the bibliography at the end of the chapter. What is the outcome? From all the important studies we get evidence that an experience may affect a later experience. What we do today determines and limits in some measure what we can do tomorrow. The formation of habit X today can facilitate the formation of habit Y tomorrow, while it may interfere with the formation of habit Z. Knowledge which I acquire today may facilitate what I undertake to do tomorrow, but it may also hinder by giving an attitude or a mode of attack not applicable. Into the interpretation or mastery of a new experience, we carry our old experience. Some aspects of the old experience will be available in mastering the new; other aspects will not, and may actually hinder in mastering the new.

Interpretation and Explanation of the Results.—The following factors probably explain most of the phenomena of transfer:

(1) *Identical elements.* (a) In habit-formation. If habit X is formed, and afterward, a complex habit Y is formed—a habit in which X is a constituent part—then Y is more easily formed because of the previous formation of habit X. To illustrate: Addition is a part of multiplication. Multiplication is more easily mastered if addition is previously mastered. In general, mastery of any process will facilitate the mastery of any other process in which the one first mastered is a constituent part. (b) In knowledge-getting. What is true in habit-formation is also true in knowledge-getting. Acquiring one bit of knowledge facilitates the acquisition of other related knowledge. The mastery of zoology is easier after the mastery of botany, for many facts are common to the two sciences, and their methods are largely the same, the tools of study and investigation, largely the same. For example, one learns to use the microscope in one study and this skill is profitable in the other. One learns many facts about cells, development, and heredity in the one that contribute to an understanding of the other. Similarly, mastery of Latin assists in the study of French because of common elements in the vocabularies. Higher mathematics involves algebra; physics and chemistry involve mathematics. In general, any study will be more easily mastered if the learner has previously acquired knowledge that contributes to an understanding or explanation of the principles of this study, or a method that can be successfully used in it.

(2) *Attitudes, and Methods of Attack.*—In learning one thing, a person not only forms a definite habit or gets definite knowledge, but gets a general scheme of attack, a point of view or a method that will be carried

into other situations. In sorting cards into one row of boxes, one not only forms the definite bonds involved, but forms schemes of association which assist the memory and are available in learning to sort into a different row of boxes. In mastering any study, one not only masters the *content of that study,* but *learns a certain method of mastery,* and this method he carries into the mastery of another study. Some aspects of the method may be applicable in that other study, some may not. In solving puzzles, as Ruger found, subjects learn certain principles, certain schemes of solving puzzles which are applied to the solution of new puzzles. They may work, they may not, it depends on the puzzle. In science one learns always to *look for causes.* One comes to take the attitude that every phenomenon has a cause. This attitude of looking for causes, the scientist carries into the solution of new problems. The mathematician forms the general attitude of trying to get a quantitative statement to apply to every fact or condition. He always wants to get some sort of graph or curve to see what light it may throw on the nature of his data. The lawyer, the doctor, the minister, form attitudes peculiar to their profession. Out of most studies, there come, therefore, not only specific content of habit and knowledge, but by-products of method, attitude, and definite schemes of orientation.

(3) *Ideals.* Related to attitudes are ideals of accuracy, ideals of thoroughness, ideals of intellectual honesty, ideals of perseverance, ideals of doing one's best under all circumstances, and these ideals may carry over into new experiences. Of course, ideals may have all degrees of generality, but whatever degree of generality they have, they carry over from one experience to

others. Honesty, for example, can be general or can apply only to certain types of situation. It is important to know that it *can be general*, and usually *is* general. A human being is very much of a piece, and general principles color our whole life. It may be, as Bagley holds, that ideals of neatness may be either specific or general, but it is important to know that they *can* have generality. All ideals have some degree of generality. Honesty and truthfulness, if we possess them at all, to some extent permeate our being and enter into all our acts. A person can form an ideal which will not allow him to do a poor piece of work. Such an ideal then affects all he does. He is unwilling to do anything poorly. On the other hand, one can have such an ideal which applies only to certain work. In doing other work, he will not care. *But we do get ideals and we do carry them over to other work.*

(4) *Confidence.* Successful mastery of a problem or a process gives confidence in attacking similar problems, and this confidence is no small factor in leading to success with these problems. It enables one to put forth all his energy and to persist till success comes. This factor is of unusual importance in education. For example, if a child is fortunate in his early experience with mathmetics, he succeeds. He likes it because he succeeds. He studies mathemathics more and more because he likes it. The more he studies it, the more power he has in it. On the other hand if he is unfortunate, he does not like mathematics, he has not faith in his ability in it. As time goes by, he has less and less power in it because of neglect of it. And in general, success or failure has a great effect on our lives because

of the effects they have on our future efforts. The man who succeeds, has more and more confidence in his abilities. He comes to attack all problems with great confidence, and this attitude has a great deal to do with continued success. While failure makes one distrust his powers, he attacks problems with a faint heart and little courage, and is doomed to failure. Success breeds success, and failure breeds failure.

(5) *Attention.* There is no question that certain aspects of what we call attention can be trained and have some degree of generality. In the first place one can learn to stick to a task. One can learn in studying Latin, for example, to set apart certain hours for study, to take precautions not to be interrupted, to keep in good condition for study, etc. In taking up another study, all these habits, ideals and attitudes will be helpful. There is a certain training in what may be called concentration, that is not a myth, but a very real thing. One can learn to gather himself together and devote himself to the task in hand, and this attitude of attention will be helpful in every thing which he undertakes. The evidence seems pretty clear that, at least in the early life of children, we can somewhat extend the range of attention. One can learn through practice in so-called mental arithmetic, to hold things in mind and manipulate them. Such training has, to some extent, general effects. The work of Aiken and Dallenbach seems to make it evident that we can, to some extent, improve certain aspects of attention, and that this improvement has some degree of permanence and generality. We can, then, be trained to stick to a task, to work with all our power while we are at it, and to hold facts in

mind for mental manipulation. The influence of this training is not wholly narrow and specific.

Other factors of transfer have been given by various writers, but they are merely other names for the factors which we have enumerated. The fact is, all these factors might well be called, as done by Thorndike, *identical elements*. Habits, knowledge, ideals, and attitudes that result from our experience are carried into new experiences, and color and affect those new experiences. It could not be otherwise. We have nothing to carry into a new experience but our old experience. But it will be a mistake if we suppose that our old experience will always be helpful, will always be adequate. We shall make a mistake if we assume that certain kinds of training will give the mind strength in general and make it able to cope with all kinds of situations. We form certain habits and acquire certain knowledge. This is all we have to help us in a new situation. Some knowledge and some habits will be much more helpful in a given situation than other habits and other knowledge. Furthermore, a habit is a specific thing. A certain stimulus touches off a definite response. The new situation must have something corresponding to the definite stimulus *or the response will not come.* A certain bit of knowledge might help in a given situation, but it will be of no avail unless something in the new situation *brings the bit of knowledge to mind*. We sometimes speak of the mind having power and of increasing that power. But the only sense in which the mind can have power is in the person's possessing available habits and knowledge and methods applicable to the situation in question, and in the habits and knowledge being brought to bear through properly organised association.

There is nothing mythical or mysterious about the whole matter. Either all experience transfers or none of it does; it all depends on how we look at the matter. A given muscular response must have its *adequate stimulus* or it does not come. A needed idea does not come to consciousness except by some organised associative route. The mind has power if it has available and usable habits, knowledge, and attitudes.

Generalised Experience.—The discussion of the preceding paragraph leads us to consider a matter clearly presented by Judd, namely the importance of generalising our experience. Whether and to what extent habits, knowledge, ideals, and attitudes function in a new experience depend to a large extent upon their organisation. In the various branches of study, one gets various facts about the world. These facts are abstract and isolated. To be useful in the future they must have an interorganisation that will make them available when they can be useful. One of the great dangers of school and college instruction is abstraction and isolation. We too often learn facts out of their natural setting, and when such setting comes, the facts do not come to mind because it has never really been coupled to that situation. It is the duty of teachers and parents to assist children in learning things in as nearly as possible their natural setting and in making helpful and profitable associative connections, so that the knowledge will be usefully available in the future. Book-learning, as compared to learning from actual life-situations, is poor. To make effective a fact learned from a book, the fact must be coupled to our actual experience with the world of things, the world of forces, the world of people. It must be extended in its connections to all imagined or re-

membered situations in which it is likely to be helpful. All isolated facts must be organised not only with reference to our experience, but with reference to other facts, laws and principles, so that we can go in thought from one fact to other related facts. The mere having an experience is no guarantee that the experience will come up in memory and help us when it might be helpful. Whether it comes or not depends on organization. Every phenomenon has intricate and far-reaching relations to other phenomena. For us to profit from our experience with a phenomenon, we must know its relations. Truly knowing the phenomenon means *knowing these relations*. We do not know a fact in any helpful way until we have generalised it and carried the generalisation over to its multitude of applications. This discussion carries us back to our previous discussion of meaning. The important thing about a fact is its meaning, its relation to the world of other facts.

It turns out that those psychologists who hold to the specific nature of learning are right. All learning consists in bonds. But these bonds can be of such nature as to make our learning more or less generally available. Indeed, our solution of a new problem will depend upon such general availability. If I can not solve a problem by using remembered facts and remembered methods or other methods which they suggest I am not likely to solve the problem, unless by fortunate accident. Even the accident is likely to be the result of persistent attack which previous experience has taught me.

Chemistry, physics, geology, history and all other subjects are useless taught merely *as such*. All their facts must be related by me to the life I live to be of

use to me. Briefly, we are always to ask in the face of a new fact, what does it mean? What new light does it throw on my world? What are its consequences? What facts are related to it? In what generalisation does it find a place? What are the uses to be made of it?

Formal Discipline. — What bearing have the facts which we have considered and the inferences we have drawn from them on the question of formal discipline? To make our answer perfectly clear we must define formal discipline. The doctrine of formal discipline is that the mind gains strength through use and that this strength is generally available in whatever the mind undertakes to do. For example, one could spend many years studying mathematics, through this study the mind acquires strength to solve all its problems of whatever nature. There is no evidence that formal discipline in this sense has any foundation. Years spent in studying mathematics would help us to solve problems where mathematical knowledge would be helpful and where its method would be available, but would not help us to solve other problems. It is true that nearly all problems have a quantitative aspect. Mathematical facts and methods, therefore, have a wide application. But no mathematical knowledge would enable me to know whether to give a child, for a certain sickness, quinine or calomel. Mathematics will help me in solving problems of quantity but not questions of quality. Of course, in the study of mathematics, I could acquire habits of application, habits of care, habits of honesty, that would be very useful in other studies. But the only sense in which mathematics, or any other study, can give me mental power is through the habits, knowl-

edge, ideals, and attitudes which they give me. Therefore, every study must have in itself its only justification. Every study must stand on its own legs. I must study neither Latin nor zoology for any general mythical powers which they are supposed to give me, but for the habits, knowledge, and ideals which they do give me. If Latin has anything in itself worth while which I want, then I must study Latin, unless, perchance, I choose to study something else which will give me something which I think more worth while and want more. What, then, does Latin give me if I study it? If I study it long enough, it gives me the ability to read an old literature in its native tongue, which means to get certain ideas through other symbols than our ordinary English words. Is this literature, or any literature any better got through one form of symbols than through another? No, in so far as literary value depends on ideas, it makes no difference through what symbols we get the ideas. If the value of a piece of literature depends largely on its form, most of this value will be lost in translation. The *Aeneid* is a story which can be told in our language as well as in the dead Latin language. The same is true of all literature.

What about algebra? Shall I study algebra? "Yes," if I want the tools which algebra gives me. "No," if I do not. To all studies, we should put the same question, What do you have for me? What is the specific contribution which you can make to my life? What knowledge can you give me which will help me to solve the problems which I shall have to solve? What needed skill will you give me? Unless there is some specific contribution to be got from a study, I am not justified

in studying it for such by-products as it may give me, for there are other studies which are valuable in themselves and have the same by-products. I need not study Latin, nor Greek, nor Sanscrit, nor anything else to learn concentration when I can study something else more valuable in itself to my life in this present day, and which will serve just as well as a means of acquiring habits of application and concentration.

Interference.—The problem to be considered here is the result of trying to form two mutually interfering habits at the same time. The most extensive experiments bearing directly upon this problem have been with card-sorting. Brown used playing cards, having his subjects sort them into four piles according to suit. They used one scheme one day and a different scheme the next day, and so continued to alternate from day to day. Brown concludes: "The inference to be drawn from these experiments is that learning to do a thing in two different ways is not detrimental. It may be helpful."

I have performed extensive experiments similar to Brown's. My subjects sorted 150 cards into 30 boxes. The boxes were numbered from 11 to 40. The cards were numbered correspondingly, five to each number. One group of four subjects sorted an hour a day for 15 days with one arrangement of the boxes and then for 15 days with a different arrangement of the boxes. The boxes had the same numbers in both cases, but a different arrangement. Another group of subjects sorted for 30 days alternating from day to day from one arrangement to the other. The first method of forming the two mutually inhibiting sets of habits was clearly

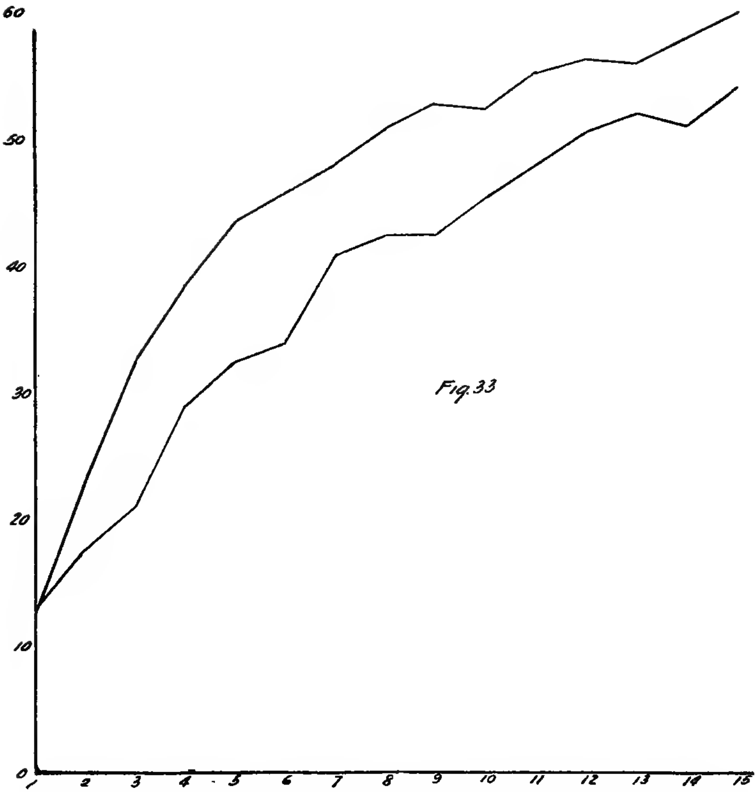

FIGURE 33. LEARNING CURVES, CARD-SORTING EXPERIMENT. The upper curve shows the results of sorting 150 cards into 30 boxes with a certain scheme of numbering, practice one hour a day for 15 days. The lower curve shows the results obtained from a different group of subjects who sorted for 30 days alternating one arrangement with a different arrangement. The lower curve shows the effects of interference. The scores are cards sorted per minute.

the best. My experiment is essentially different from Brown's. Sorting cards into four piles is a different sort of thing from sorting them into 30 piles. When one sorts playing cards into four piles, he very quickly gets the pattern of the arrangement, and after only a few minutes, sorts with great speed. But this is not true when the number of bonds to be formed is great. Although my four subjects using the alternating method were slightly better learners than the other group, the results of their method were poorer. On the basis of my experiments, I should say that if one has two complicated sets of mutually interfering motor habits to form, the most economical procedure is to form one set, then the other.

That two mutually interfering sets of habits can exist side by side in the same individual has been established by many investigators. In the card-sorting work of Miss Howe, already mentioned in previous chapters, practice with two interfering habits was carried further than has ever been done before. Her experiment extended over a period of seven months. She practiced on one scheme till she acquired great speed, then acquired speed in the other scheme. She alternated from one scheme to the other during the same hour, continuing with one scheme, however, till she reached maximum speed, then turning to the other. Finally, she alternated directly from a sorting with one scheme to the other. At her last sitting, she made the following records, which are the number of seconds required for sorting the 150 cards: (The first number represents one scheme; the second, the other, and so on) 112, 112, 112, 112, 110, 107, 116, 120, 112, 117.

This represents the placing of the cards at the rate of about two-thirds of a second to each card, which is a very great speed.

An interesting question is: Is habit interference greater with fast learners or with slow learners? Brown found that interference was greater with fast learners but that they overcame it quickly. My own experiments seem to confirm Brown's conclusion, but the matter is not definitely settled, and forms an interesting problem for the future. Interference is certainly very different with different individuals. In the mirror writing experiment, which involves the interference of old habits in the formation of new, some subjects can write the whole alphabet in two or three minutes, while some subjects can not do it in a whole afternoon. Just what causes this great difference has not yet been determined. We do not yet know just what type of person suffers most from interference, nor do we know whether it is an advantage or a disadvantage to suffer from interference. If one's old habits resist change, that makes for stability; on the other hand, it works against progress when progress means the breaking up of old habits.

EXPERIMENTS AND EXERCISES.

1. Only a simple experiment in transfer can be undertaken as a matter of demonstration and illustration. If the following experiment has not already been done it should now be done. Use five rows of the card-sorting boxes. Make two sortings for each row. This can be done in an hour. Note that the scores for each succeeding row are better than the preceding scores. How many causes for the improved scores can be discover-

ed? If time is available, the instructor can repeat any of the shorter experiments reported in the chapter or discussed in the references, but transfer experiments, as a rule, are too difficult to be undertaken as a class exercise.

REFERENCES.

Bagley, W. C. and Squire, C. R., *Experiments on transfer of ideals of neatness*, in Bagley's *Educational Values*, 1905, 188.

Bair, J. H., *The practice curve*. P. R. Mon. Sup., No. 19, 1902.

Bergstrom, J. A., *Experiments upon physiological memory by means of the interference of associations*. A. J. P., V, 1893, 356.

The relation of the interference to the practice effects of an association, A. J. P., VI, 1894, 433.

Brown, W. *Habit interference in card-sorting*, Univ. of California Publications in Psychology, Vol. 1, No. 4, 1914.

Coover, J. E. and Angell, F., *General practice effect of special exercise*, A. J. P., XVIII, 1907, 328.

Cowan, E. A., *An experiment on the influence of training on memory*, J. E. P., VII, 1916, 31.

Culler, A. J., *Interference and adaptability*, Arch. of Psych. No. 24, 1912.

Cummins, R. A., *A study of the effect of basket-ball practice on motor reaction, attention and suggestibility*, P. R., XXI, 1914, 356.

Dashiell, J. F., *A comparison of complete vs. alternate methods of learning two habits*, P. R., XXVII, 1920, 112.

Dearborn, W. F., *The general effects of special practice in memory*, P. Bul., VI, 1909, 44.

Ebert, E. and Meumann, E., *Ueber einige Grundfragen der Psychologie der Uebungsphänomene im Bereiche des Gedächtnisses*, Arch. f. d. gesamte Psych., IV, 1904, 1.

Evans, J. E., *The effect of distraction on reaction time with special reference to practice and the transfer of training*, Arch. of Psych. No. 37, 1916.

Fracker, G. C., *On the transference of training in memory*, P. R. Mon. Sup., No. 38, 1908, 56.

Gilbert, J. A. and Fracker, G. C., *The effects of practice in reaction and discrimination and discrimination for sound upon the time of reaction and discrimination for other forms of stimuli*, Univ. of Iowa Studies in Psychology, I, 1897, 62.

Hewins, N. P., *The doctrine of formal discipline in the light of experimental investigation*, 1916.

Judd, C. H., *Practice and its effects on the perception of illusions*. P. R., IX, 1902, 27.

The relation of special training to general intelligence (with Scholkow), Ed. Rev., XXXVI, 1908, 28.

Kline, L. W., *Some experimental evidence in regard to doctrine of formal discipline*, J. E. P., V, 1914.

Leuba, J. H. and Hyde, W., *An experiment in learning to make hand movements*, P. R., XII, 1905, 351.

Lyans, C. K., *The doctrine of formal discipline*, Ped. Sem., XXI, 1914, 343.

Miles, W. R., *A study in the correlation of elementary and high school grades*, J. E. P., I, 1910, 537.

Poffenberger, A. T. *The influence of improvement in one simple mental process upon other related processes*, J. E. P., VI, 1915, 459.

Pyle, W. H., *Transfer and interference in card-sorting*, J. E. P., X, 1919, 107.

Reed, H. B., *A repetition of Ebert and Meumann's practice experiment in memory*, J. Exp. Psych., II, 1917, 315.

Ruediger, W. C., *The indirect improvement of mental functions through ideals*, Ed. Rev., XXXVI, 1908, 364.

Ruger, H. A., *The psychology of efficiency*, Arch. of Psych. No. 15, 1910.

Rugg, H. O., *The experimental determination of mental discipline in school studies*, 1916.

Sleight, W. G., *Memory and formal discipline*. B. J. P., IV, 1911, 386.

Starch, D., *Transfer of training in arithmetical operations*, J. E. P., II, 1911, 306.

Thorndike, E. L. and Woodworth, R. S., *The influence of improvement in one mental function upon the efficiency of other functions*, P. R., VIII, 1901, 247, 384 and 553.

Wallin, J. E. W., *The doctrine of formal discipline; two neglected instances of transfer of training*, J. E. P., I, 1910, 168.

Washburn, M. F. and McMein, M., *The effect of mental type on the interference of motor habits*, A. J. P., XX, 1909, 282.

Winch, W. H., *The transfer of improvement in memory in school children*, B. J. P., III, 1910, 386.

Additional researches in learning to spell, J. E. P., VII, 1916, 93.

Further work on numerical accuracy in school children, J. E. P., II, 1911, 262. See also same journal, 1910, 557.

The transfer of improvement in memory in school children, B. J. P., II, 1908, 284.

Woodrow, H., *Practice and transference in normal and feeble-minded children*, J. E. P., VIII, 1917, 85 and 151.

CHAPTER XII.

FATIGUE AND LEARNING.

Nature of Fatigue.—The subject of fatigue has been studied by both psychologists and physiologists. Many experiments have been performed. The literature of the subject is voluminous. It is difficult to sift the mass of results and determine what is established and what is not. The results, in many cases, are conflicting and inconclusive. The phenomena of fatigue are so complex, and so combined with all sorts of other phenomena that the experimenter finds it difficult to assign results to their proper causes. The phenomena nearly always appear in connection with practice effects, the one offsetting the other. Moreover, an adequate measure of fatigue, universally applicable, has not yet been discovered. Many of the physiological phenomena due to fatigue are also produced by other causes. Fatigue produces inability to work, but the work curve also falls because of many other causes, such as loss of interest, monotony, etc. It shall be our purpose in this chapter to present such facts of practical importance as seem to be definitely established. And, in spite of the fact that the psychology of fatigue can not be finally and definitely written, there is a respectable body of facts fairly well established.

The fatigue of an organ is merely a reduced capacity to function brought on by work. In the functioning of the various organs of the body, their tissues are torn

down and the products of the katabolic processes are eliminated by various excreting organs. When work is of such amount that the waste products can not be eliminated as fast as produced, they are scattered over the body by the circulation and produce the effect known as fatigue. This effect is essentially incapacity to work. That the toxic substances produced in our bodies by the functioning of its organs lower their capacity to function is definitely known, but just how they produce this incapacity is not known. It seems pretty clear that it is a nervous phenomenon. The fatigue poisons seem to lessen the conductivity of the nerves, thereby lowering their functioning capacity. Fatigue is therefore loss of ability to work, not so much because of lack of energy as because the energy is not available.

The recent discoveries of a German physiologist seem to make conclusive the evidence that fatigue is due to certain toxic substances produced in the body. He found that certain antitoxins which he introduced into the body of his subjects counteracted the toxins produced by work. His experiments were conducted with guinea pigs and school children. By injecting the antitoxin into guinea pigs, he lessened fatigue in them. On school children, he performed the following experiment. A number of school children were divided into groups. The children of each group were required to do hard work in arithmetic. One group worked in a room the air of which contained the antitoxin. The pupils of this room suffered less from fatigue than the children who did not breathe air containing the antitoxin.

Measures of Fatigue.—Nearly every sort of mental and physical performance has been used as a measure of fatigue. In the earlier work some kind of physical test was usually used, especially aesthesiometry and dynamometry. The attempt was also made to determine the presence of fatigue by changes in the circulation and respiration. While fatigue does produce definite changes in both circulation and respiration, these changes are also produced by other causes, and are intimately connected with the emotions. Therefore when these changes occur, it is difficult to know what factor or what combination of factors has produced them. In practice, it is difficult to use any of the physiological methods with any degree of certainty. The school teacher is concerned with the fatigue of children due to mental work. As a measure of mental fatigue, certain mental tests have proved far more successful than any of the physiological methods. A fairly successful method of measuring general mental fatigue is to take the measure of some simple mental function after first bringing the function to maximum efficiency through practice. For example, we can use auditory memory span for digits. We first bring this span up to its maximum through practice. Then we apply the test as a measure of fatigue on the assumption that fatigue will narrow the memory span. This is typical of the more successful fatigue experiments. The purpose of bringing the function up to its maximum efficiency before using a measure of its efficiency as a criterion of fatigue is to prevent practice effects from offsetting the effects of fatigue.

Another successful method of studying fatigue is to measure the decrease in efficiency of some task continu-

ously performed. School children can be kept at work continuously on some definite school task, as an exercise in arithmetic, and measures be taken of their efficiency at successive intervals of time. If practice effects are eliminated or accounted for, the amount of fatigue is indicated by the loss in efficiency. Such a method was used by Thorndike, Arai, and others.

Kinds of Fatigue.—When fatigue is occasioned by mental work, it is called mental fatigue, when it is occasioned by muscular work it is called bodily or physical fatigue. Its nature is the same however caused. If fatigue is very great, its effects are general; if not very great, its effects may be to some extent only local or specific. Owing to the effects of loss of interest in work, it is difficult to determine to what extent fatigue is general. Some experiments seem to indicate that in the case of mental fatigue, there is still ability to do physical work. And when one is so fatigued that he can not pursue the same kind of mental work profitably, it is often found that he can do some other kind of mental work with profit. This is probably not because mental fatigue is to a very great extent specific, but because it is *relative*. One can pursue one kind of mental work till the fatigue is so great for the interest in that subject that further work is not profitable, while work will still be profitable in another field where interest is fresh. This is not because there is more energy for the other field but because *interest makes the energy available*. Common experience as well as experiments seem to indicate that when mental fatigue is very great, one is incapacitated for any kind of mental work. On purely *a priori* grounds, it would seem that fatigue must necessarily be rather general, for as the

fatigue poisons accomulate, the circulation will scatter them till they affect the entire nervous system. Incapacity to work due to fatigue seems not to be because of depletion of the nervous or muscular tissue but is due to the effects of the poisons upon the nervous system. Certainly, very great fatigue due to muscular work incapacitates one for serious mental work. Winch's experiments with the students in evening schools would seem to corroborate this view. These students were for the most part clerks who during the day were engaged in work chiefly physical. They fatigued so readily in the work of the night school, that Winch drew the conclusion that such work was not profitable.

Fatigue of School Children.—The first important practical question to raise is concerning the amount of fatigue occasioned in school children by the ordinary work of the day. Careful experiments have been performed by several investigators which throw light on this question. The experiments of Winch, Gates, Thorndike, Heck and others are fairly unanimous to the effect that the regular work of the school occasions very little fatigue. Winch found that children 6 and 7 years old were more fatigued in the afternoon than were children 11 years old, and those 11 years old more than those 13 years old. The extensive studies of Heck on fatigue of school children led him to the following conclusion, which I give in his own words: "Mental fatigue in relation to the daily school program is far less than is generally believed. The small amount of fatigue noticeable during the school day was more probably caused by improper conditions of ventilation, lighting, etc., than by the school work itself. Unhygienic conditions in the school and physical defects, however

slight, in the children are undoubtedly the great causes of fatigue in most schools. The decrease in quality of work of children as the day advances, supposed to be more or less general in schools, is due less to a using up of the energy-producing materials in the nerve cells of the body and an autopoisoning of the nervous system by the waste products from this process, than to a loss of interest in the school work with its lack of vital and varied appeal and its monotony of instruction and environment. The bored child unconsciously or consciously, rebels and does a less correct amount of work. Continued work produces boredom and continued boredom decreases efficiency, on account of the close mutual relation between physiological processes and mental attitudes. With sound bodies, a hygienic school, proper classification, frequent relaxation, a vital and varied curriculum, and live teachers, most children will show no problem of fatigue in relation to the daily school program. However, the individual variations in fatigue in children of the same class are so great that the teacher is under constant obligation to watch the easily fatigued child and decrease his work whenever necessary below the requirement for the class as a whole." The work of Thorndike leads to a similar conclusion. Under the author's direction extensive experiments have been carried out in several city school systems in three states to determine the learning capacity at the end of the day as compared with the learning capacity at the beginning of the school day. I did not attempt to measure fatigue, but to find an answer to this question: Is the capacity of school children to learn in the late afternoon any less than it is at the beginning of the school day? The Whipple digit-symbol

substitution test was used in these experiments. The results of the various experiments were in general agreement. The ability to learn just before dismission in the afternoon was only about 2 per cent. less than in the morning. Our results are therefore in agreement with those of Heck and Thorndike.

The Course of Daily Efficiency.—Similar to the question just discussed is the problem of the change of working efficiency during the course of the day. But this is not precisely the same question, although it is related to the question of fatigue. After we awake in the morning from sleep, we have recuperated from the fatigue of the preceding day, but are not able to do our most efficient work of the day. During sleep the functioning of the various organs of the body is suspended or partially suspended. After we awake, it takes some time for them to rise to their maximum efficiency. Winch, using arithmetical reasoning as a measure of efficiency, studies children of both sexes and various ages and finds that at 11:30 they do on the average 5.6 per cent. better than at 9:40. But in one school Winch obtained different results. This school was in a poor neighborhood. The pupils were the children of laborers and got up earlier in the morning than did the children of the other schools. The pupils in this school reached maximum efficiency earlier than the children who got up later.

The extensive studies of Gates are in agreement with those of Winch. Gates' first study was with fifth and sixth grade school children. He used as tests of efficiency, addition, multiplication, auditory memory, visual memory, recognition, completion, cancellation, and speed and accuracy of movement. His results are re-

produced in Figure 34. In the more purely mental functions there was an improvement up till nearly twelve o'clock, a decline at one o'clock, with some improvement up to three o'clock. The motor tests show an improvement throughout the day. There is better muscular control and better speed the latter part of the day.

Gates performed similar experiments with 165 college students. With these students he used as tests, auditory memory, visual memory, substitution, recognition, and logical memory. The combined results of all the

TABLE 35 (FROM GATES).

Hour	8:00	9:00	10:00	11:00	1:00	2:00	3:00	4:00	5:00
Auditory memory:									
Mean	100.0	97.5	98.8	100.3	97.4	94.5	98.2	95.5	93.8
Median	100.0	103.0	103.0	107.0	105.8	103.9	105.8	101.4	101.0
Visual memory:									
Mean	100.0	99.3	101.5	107.0	105.8	103.9	105.8	101.4	101.0
Median	100.0	100.0	103.0	101.5	96.7	100.0	104.0	101.5	100.0
Substitution:									
Mean	100.0	102.7	105.2	104.3	96.0	102.6	101.5	101.2	94.3
Median	100.0	101.2	104.0	103.4	95.5	97.2	97.7	97.7	95.3
Recognition:									
Mean	100.0	115.7	122.2	115.7	106.5	111.0	120.0	120.0	118.5
Median	100.0	108.0	117.0	112.0	96.4	99.0	117.0	121.0	117.0
Logical memory:									
Mean	100.0	109.0	107.7	103.0	95.5	99.3	101.4	102.2	91.3
Median	100.0	107.3	103.7	105.1	100.0	100.0	103.7	100.0	93.3
Average	100.0	104.3	103.6	105.6	98.7	100.6	105.1	104.2	100.4

In the above table from Gates, the eight o'clock records are taken as the standards of comparison and called 100. The records for the other hours are expressed in terms of per cent. of the eight o'clock records.

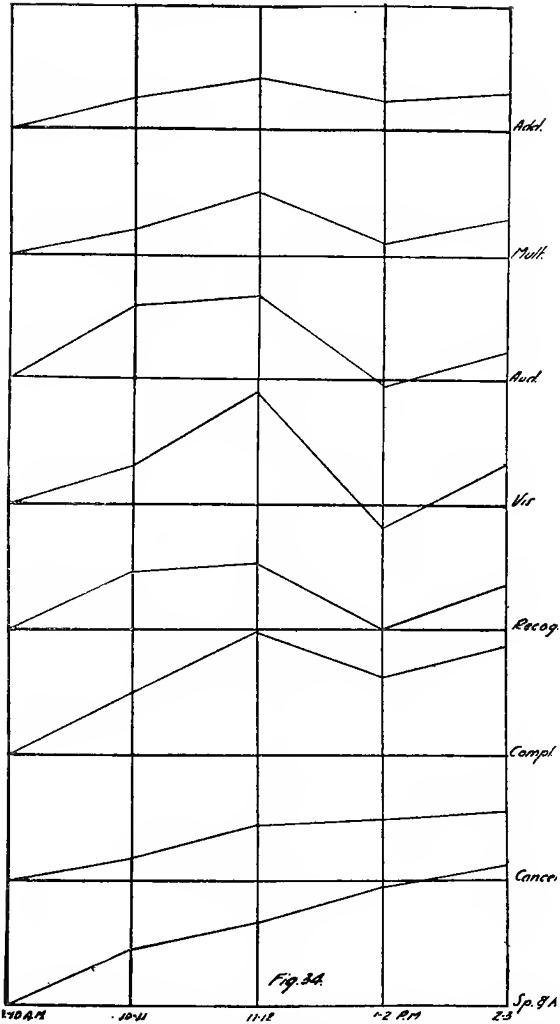

FIGURE 34. FROM GATES. The graphs show the course of efficiency during the day. Add.=addition; Mult.=multiplication; Aud.=auditory memory; Vis.=visual memory; Recog.=recognition; Compl.=completion; Cancel.=cancellation; Sp. and Ac.=speed and accuracy.

tests are shown in Figure 35. The results are much the same as those obtained from the children. There is improved efficiency till nearly noon, lowest efficiency about one o'clock, an improvement till about three, a slight falling off at four and still more at five. In Table 35 are shown in tabular form Gates' results from the students. The first record of the day is called 100, and the other records are expressed in terms of per cents. of this initial record. It is interesting to compare his results from the substitution test with those of the author, mentioned above, obtained from school children of all ages. At 9:25, the adults made a score of 179 digits, and at 3:25 a score of 177 digits, only about 1.3 per cent. less. The difference in the case of the children in our study was just a trifle more, *i. e.*, the children were not quite so efficient in the late afternoon as compared with morning efficiency as was the case with the older students. It will be remembered that Winch found the younger children showing more fatigue as the day progressed than did the older children. From many sources the evidence is clear that children fatigue more readily than do older people. Children are not capable of such long sustained effort as is the case with adults. This is doubtless partly, though not wholly, due to lack of habituation.

The practical significance of these studies on the course of diurnal efficiency is as follows: Neither children nor adults are capable of the best work early in the morning. They gradually come into the full swing of their power, and just before noon are able to do their best work of the day. Just after noon, their powers are at the lowest ebb for mental work, with some in-

crease in efficiency toward the end of the school day. In arranging the school work of the day, then, the most difficult work should be placed at the last morning period; the least difficult just after noon. It has been suggested that motor work, such as drawing or writing might well come in the first afternoon period. While mental efficiency is lowest at this time, motor efficiency is higher than at any earlier period, though not so high

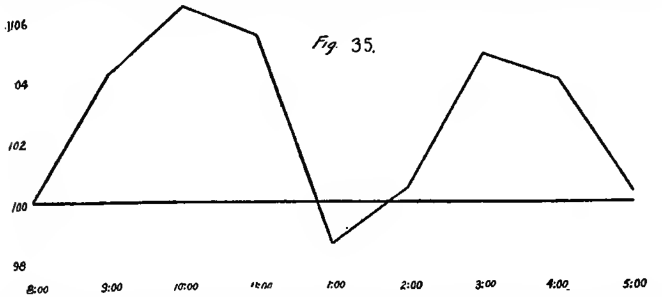

FIGURE 35. The graph shows the course of efficiency during the day in the case of college students. The horizontal line represents the efficiency at eight o'clock. The efficiencies for the other hours are represented in percents of the eight o'clock efficiency.

as later in the afternoon. While these differences are not very great, they are great enough to be taken into practical account. If, for example, we wished to get the maximal effort from children in a mental performance, we should have them work from about 10:30 to 11:30. If we wish to get the maximal physical effort, we should have the work from about three to four o'clock. The accompanying conditions must be taken into account, however. The above facts are approximately true if the subjects are doing the ordinary school work, but are probably not true under other conditions. If the children should work at a much higher level of efficiency

than is ordinarily the case in school, the point of highest efficiency would doubtless be shifted. It would probably come earlier. And if instead of doing the ordinary school work, they should be engaged in hard manual work, the point of highest efficiency at such work would doubtless come earlier than four or five o'clock.

The work of several intestigators makes it appear that mental fatigue comes earlier than physical fatigue, under the same conditions of mental and physical work. If one works at hard mental work, fatigue comes earlier than if one works at hard physical work in a field where he is habituated. As mentioned above, fatigue is largely a nervous phenomenon. In mental work, the nervous system is much more fully involved than it is in physical work.

Continuous Work.—From the laboratory of Professor Thorndike have come some interesting studies of long continued work of the same kind. The most notable work is that of Arai. This investigator practiced herself at mental multiplication of five place numbers, and then worked for a long period. The notable thing in the results is that efficiency continued for so long a time with little falling off.

Painter performed a similar experiment. Painter first reached stability through practice, then worked from 11:00 p. m. till 3:07 a. m., multiplying four place numbers. Inability to work seemed to come rather suddenly. He concludes: "There exists a definite and relatively abruptly appearing point beyond which mental work becomes impossible." It seemed to Painter that there was no "tailing off." He was not only unable to multiply four place numbers but was unable to do

anything. Such a conclusion can not be accepted without further confirmation. Other experiments indicate that inability to work comes on by degrees. Memory span, for example, does not suddenly jump from the normal span to zero. Painter was working with an habituated process. It is possible that in the case of habituated processes, even though they are complex, inability to work may come rather suddenly, and that when one is unable to carry on such a process he is practically unable to do anything.

In accepting Thorndike's conclusions in regard to our ability to do long-continued work without much fatigue and without much diminution in our ability to perform the work, a certain distinction must be kept in mind, namely, the difference between habituated and non-habituated work. Fatigue comes much more quickly in non-habituated work. The author once undertook to learn the point alphabet of the blind. Fatigue was so great that rest periods had to be allowed every fifteen minutes. When children are learning to write, or trying to master any difficult feat of muscular coordination, fatigue comes very quickly, and rest periods should be frequent. In establishing new bonds in mental learning, fatigue also comes very quickly.

For still another reason the distinction between habituated and non-habituated work must be kept in mind. As has been shown, one can perform a task in habituated work for a long period of time with little diminution in effectiveness. If one starts out to do a non-habituated task, one's efficiency rises for a time and then fails to rise any more during the work period, even though work continue for hours. Efficiency may remain at very near the same level, just as in the habituated

performance it remains at nearly the same level. But two other things besides efficiency are to be taken into account. In the case of the non-habituated performance, although the level of work remains about the same, the effect of the work in fixing the habit after the first three or four half-hours is practically nothing. Effective learning can not go on unless fatigue is at a minimum. And in the case of habituated work, although one can maintain the same high level of efficiency for a long period of time, that the after effects of a short period of work are the same as for a long period has not been demonstrated. The evidence points in the other direction. For long continued work, one pays the penalty afterward, as is indicated by the work of Smith which is discussed below.

Fatigue Antitoxins.—In a preceding paragraph the discovery of a fatigue antitoxin was mentioned. This antitoxin introduced into the circulation of an animal delayed the effects of fatigue. The work of Miss Smith makes it look as if the body itself produces an antitoxin which in some degree neutralises the effects of fatigue. Smith withheld sleep and then noted the effect on work. At first, the effect of loss of sleep seemed to enhance work, but later, after a day, or two or three or four days, work suffered from the loss of sleep. We can not consider such a notion established, but many phenomena seem to support Smith's inference as to the bodily antitoxins. Such a theory would explain the results of Thorndike, Arai, and Painter, and the common observation of every day life of people who work for long periods at a high tension and then suffer from complete exhaustion. If as soon as waste products are produced in the body, the body sets to work not only to

eliminate them but to neutralise them, one ought to be able, under sufficient incitement to work to the point of exhaustion. In such case exhaustion would be due not only to an accumulation of the fatigue toxins above elimination and neutralization, but also to at least a partial depletion of the tissues. Our attitude toward Smith's speculation must be that of waiting for further facts.

Several experiments have been performed to determine the fluctuations in efficiency during a work period. Phillips found that in the first minute of a ten minutes practice period, 6 to 12 per cent. more work was done in the fundamentals of arithmetic than for the average of the remaining nine minutes. Poffenberger compared the two halves of a very short work period. He gave subjects tests in opposites, adding, color-naming, and cancelling, of less than a minute in length. The first half of the work was done in less time than the second half. Poffenberger's inference was that fatigue had set in in this short time, and thought fatigue not so rare as sometimes supposed. Smith's hypothesis comes to mind in this connection. It is possible that when we start to work the waste products can not be immediately taken care of either by elimination or neutralization. It doubtless takes some time for the production of the bodily antitoxins, if such a thing happens. Physiological processes can not be instantaneous. When waste products are produced anywhere in the body, it takes a measurable time for the body to establish a new equilibrium. It has been demonstrated that the functioning of the nerve fibres as well as the nerve cells requires the presence of oxygen. When a group of neurones begins to function, their supply of oxygen is tem-

porarily depleted, a new balance must be established. It can not be established immediately, for the stimulus for the increased supply of oxygen is the need of it. This explains why it takes some time for one to come into the full swing of his power. When one starts a certain piece of work, the part of the nervous system involved is rested and in full functioning condition and can do well immediately, but can not do well continuously until a new balance of performance is established among all the processes involved, elimination, neutralization, oxygen supply, or whatever they may be. The author has extensive records which show that in card-sorting, even after considerable habituation is reached, the best work of an hour's sitting is not done at the beginning, but only after the sorting has gone on for a while. The records of four subjects are shown in Figure 36. (See also Fig. 8). While there is some individual difference, all subjects agree in showing a drop in the curve or increased efficiency after the initial performance of the hour. This seems to be universally true in motor work.

Sleep and Fatigue.—The best cure for fatigue is sleep. During sleep, the body does only the work necessary to keep life going. The waste products of work are eliminated during sleep. The waste of the tissues is repaired. A stable equilibrium is established. Sleep is absolutely necessary. The body by one device or another can keep at work for some hours, but eventually it must have sleep. There must be complete cessation from all work except what is necessary to keep the vital processes going. Several authorities have published statements giving the amount of sleep required by people of different ages. One of the latest statements is from Terman and Hocking. They give not the time people should sleep but the average amount of

FIGURE 36. The graphs show the course of efficiency during an hour after habituation in card-sorting, four different subjects.

time they actually do sleep. Their data are from several places in western United States, and are shown in the accompanying table.

TABLE 36.

SHOWING THE AVERAGE TIME IN HOURS AND MINUTES SPENT IN SLEEP BY PEOPLE OF VARIOUS AGES.

Age	6-7	7-8	8-9	9-10	10-11	11-12	12-13
Amount of sleep	11:14	10:41	10:42	10:13	9:56	10:00	9:36
Ages	13-14	14-15	15-16	16-17	17-18	18-19	Univ. Students.
Amount of sleep	9:31	9:06	8:54	8:30	8:46	8:46	7:47

The hours of sleep shown in the table may be taken as fairly representative of the amount of sleep required at the different ages. Rather, they should be taken as the minimum requirements, for it is doubtful that any of the figures used in computing the averages would be too high, and it is quite likely that in some cases, they would be too low. This would make the averages a little lower than they should be.

It seems clear that some people need more sleep than do others, and doubtless the work one is doing makes some difference in the amount of sleep needed. Older people should determine by experiment how much sleep they need, and take that amount. Parents should determine how much sleep their children need and see that the children get that amount. Present social conditions in the cities make it difficult for children to get enough sleep, for there are so many attractions to keep them up and awake in the evening. They consequently go to bed too late to get enough sleep before they have to get up to get to school on time. Teachers should make a study to determine the amount of sleep taken

by their pupils, and should take such steps as are necessary to bring about the proper amount of sleep.

Terman and Hocking found no relation between amount of sleep and intelligence or success in school. This need not mean that sleep is not a factor in school success but that other factors are of more importance than the slight variation in sleep. The children gifted by nature with superior endowment are able to hold their high ranks in school with varying amounts of sleep. The children dull by nature are not able to excel by any amount of sleep. But children whether bright or dull will do their best work when they have plenty of sleep.

Experiments have shown that the most value comes from the early sleep of the night. Sleep is then deeper. After only two or three hours of sleep, a subject shows as great working capacity as if allowed to sleep the required amount. The experiments on which this statement is based did not determine how long the subjects could work, but only their efficiency for a short time. It is quite probable that an hour or two of sleep suffices for a removal of the fatigue poisons and a renewal of the oxygen supply to the neurones, but is not sufficient for a renewal of the wasted tissues. One's immediate capacity to work doubtless depends upon the amount of fatigue poisons present and on the oxygen supply in the central nervous system, but one's capacity for prolonged work depends on the amount of available energy.

If one wishes to keep his body in a high state of working efficiency, he should have enough rest during the day and sleep at night to enable the body to repair the waste of work. If one work in such a way that for a considerable time the outgo of energy exceeds the re-

pair, then he must eventually pay the penalty. In sickness the body has to make such a fight to overcome the disease that it becomes very much weakened. There is often great loss of tissue shown by decrease in weight. After sickness, children therefore fatigue very easily, and when they return to school, their work should be lightened instead of increased.

The Feeling of Fatigue.—It is of practical importance to know that the feeling of fatigue is no reliable criterion of the presence of fatigue. Fatigue may be present when one does not feel fatigued; and on the other hand one may feel fatigued when the body is not fatigued. The only sure test is the ability to work. Sometimes one feels tired and is disinclined to work, but finds that if he will start in and try, after a little time he is working with great efficiency. A very interesting phenomenon is that of "second breath," a matter not yet fully explained. One may work for a time, fatigue comes on and there is lessened capacity for work, but it is often found that if one keeps on at the work, the capacity increases again and efficiency goes up perhaps even to a higher point than at first. Such rhythms may be repeated several times in the course of continuous work. Their explanation, while not fully known, doubtless is to be found in the various physiological processes already discussed. An excess of waste products produces the temporary incapacity, and at the same time stimulates the removal and renewal processes, which presently restore the original capacity. These rhythms keep up till there is probably temporary depletion of the tissues, which only rest and sleep can cure.

Practice and Fatigue.—Several times we have called attention to the relation of practice to fatigue. Habituation reduces fatigue. When we are learning a

process fatigue is great, after we have acquired efficiency, the work can be carried on for a long period of time with relatively little fatigue. These facts should be borne in mind in school work, especially in that of young children. In trying to master the movements of writing, the young child fatigues very easily; after the process is mastered, one can write for hours with little fatigue. The same is true in all work. When the organism becomes adapted through the strengthening of the tissues and the establishment of the necessary neuro-muscular bonds work can go on for a long period of time with very much less fatigue than is occasioned earlier in the work. When a process is thoroughly habituated, it partakes of the nature of a reflex, and can be carried on all day at a high point of efficiency. The organs and tissues concerned become so adapted and adjusted that they can maintain the processes for long periods of time.

A related phenomenon is the fact that the best workers fatigue less easily than do the poor workers. The fastest workers usually make fewer mistakes than do the poor and slow workers. In the slow worker, the elements involved in the work are not so well co-ordinated; there is usually more waste of energy through interfering processes. Even in the same worker there is often found a direct relation between speed and accuracy, fewer mistakes being made in connection with the fastest speed. Some investigators have found an inverse relation between improvability and fatigue, those who improve the fastest suffering least from fatigue. These several phenomena have their chief explanation in facts of adjustment and adaptation.

Work and Oxygen Supply.—Physiological experiments have shown the necessity for the presence of oxygen in the functioning of the neurones. An isolated nerve fibre functions when oxygen is present. If it is placed in some other medium, it ceases to function. When oxygen is supplied, it functions again. These facts show the necessity for hygienic conditions proper for work. They show the importance of proper ventilation of school rooms, of the necessity for the whole breathing apparatus of the child being in perfect condition. The open-air school has fully confirmed this conclusion. One should also have constant pure air while asleep in order to facilitate the restoration of all the organs of the body to their full working power. Food, in proper quality and quantity is also necessary if children are to be in condition to profit to the full extent from instruction. It is folly to maintain schools at great expense and then go to no trouble to see that children are in proper condition to profit from the work of the schools. It is the business of a teacher not only to hold recitations, but to know that all the conditions necessary for effective work have been supplied.

The Work of Students.—University students can profit from a consideration of the facts discussed in this chapter. Their energies are often dissipated. They too often have all sorts of activities and interests which consume both their time and energy. In some cases, the night is half gone before they get down to the work which is supposed to be the proper work at a university. But the assignments must be prepared, so they work, or attempt to work, when their bodies are in no condition for work. The energy of our body is like the money in our purse. When it is gone, it is gone. If it

is spent in one way, then it is not available for spending in another way. We have to decide; we have to choose. If we spend all of our energy performing in the side shows, there is none available for the main circus.

A very serious trouble among students is that they do not keep their bodies physically fit, to be able to learn effectively. The body, after all, is a motor machine. To be maintained in a high state of effectiveness, a large amount of motor work is necessary. Few people break down on account of too much work, but they often break down on account of too much work for the conditions under which they live.

EXPERIMENTS AND EXERCISES.

1. Simple experiments showing the relation of fatigue to learning can be undertaken. The instructor and students should work out a plan for comparing the learning capacity of students under various degrees of fatigue. Nonsense syllables should be used for learning material. Various plans can be devised for inducing fatigue.

2. The course of daily efficiency can be studied after the manner of Gates. Determine the learning capacity for nonsense syllables for various hours of the day and night. The work can be much simplified by dividing the class into groups, measuring their learning capacity by identical procedure, then let different groups try out learning at different hours of the day and night.

REFERENCES.

Avai, T., *Mental fatigue*, Columbia Univ. Cont. to Ed., No. 54, 1912.

Ash, I .E., *Fatigue and its effect upon control*. Arch. of Psych., IV, No. 31, 1914.

Burnham, W. H., *Oxygen supply as a condition of efficient brain activity*, J. E. P., II, 1911, 421.

Burnham, W. H., *The hygiene of sleep*, Ped. Sem., XXVII, 1920, 1.

Dodge, R., *The laws of relative fatigue*, P. R., XXIV, 1917, 89.

Garth, T. R., *Mental fatigue*, Arch. of Psych. No. 41, 1918.

Gates, A. I., *Diurnal variations in memory and association*. Univ. of Cal. Pub. in Psych., I, No. 5, 1916, 323.

Heck, W. H., *A study of mental fatigue*, 1913.

Hollingworth, H. L., *Variations in efficiency during the working day*, P. R., XXI, 1914, 473.

Lee, F. S., *The nature of fatigue*, P. S. M., LXXVI, 182.

Marsh, H. D., *The diurnal course of efficiency*, 1916.

Mosso, A., *Fatigue*, Eng. tr., 1904.

McDougal, W., *On a new method for the study of concurrent mental operations and of mental fatigue*, B. J. P., I, 1905, 435.

Offner, M. M., *Mental fatigue*, Eng. tr. by Whipple, 1911.

Painter, W. S., *Efficiency in mental multiplication under extreme fatigue*, J. E. P., VII, 1916, 25.

Phillips, F. M., *A comparison of the work done in the successive minutes of a ten-minute practice period in the fundamentals of Arithmetic*, J. E. P., VII, 1916, 271.

Poffenberger, A. T. and Tallman, G. G., *Variability in performance during brief periods of work*, P. R., XXII, 1915, 371.

Root, W. T., Jr., *A study of mental fatigue with a group of five boys*, J. E. P., VII, 1916, 533.

Seashore, C. E. and Kent, G. H., *Periodicity and progressive change in continuous mental work*, P. R. Mon. Sup., VI, No. 28, 1905.

Smith, M., *A contribution to the study of fatigue*, B. J. P., VIII, 1916, 327.

Starch, D. and Ash, I. E., *The mental work curve*, P. R., XXIV, 1917, 391.

Terman, L. M. and Hocking, A., *The sleep of school children, its distribution according to age and its relation to physical and mental efficiency*, J. E. P., IV, 1913, 138, 199 and 269.

Thorndike, E. L., *Mental Fatigue*. P. R., VII, 1900, 466 and 547.

Mental Fatigue, J. E. P., II, 1911, 61.

The curve of work, P. R., XIX, 1912, 165.

The effect of continuous exercise and of rest upon difficult mental multiplication, J. E. P., V, 1914, 597.

Fatigue in a complex function, P. R., XXI, 1914, 402.

Wells, F. L., *Practice and the work curve*, A. J. P., XXIV, 1913, 35.

Normal performance in the tapping test before and during practice, with special reference to fatigue, A. J. P., XIX, 1908, 437.

Wimms, J. H., *The relative effects of fatigue and practice produced by different kinds of mental work*, B. J. P., II, 1907, 153.

Winch, W. H., *Mental adaptation during the school day as measured by arithmetical reasoning*, J. E. P., IV, 1913, 17.

Some measurements of mental fatigue in adolescent pupils in evening schools, J. E. P., I, 1910, 13 and 83.

Mental fatigue in day school children as measured by immediate memory, J. E. P., III, 1912, 18 and 75.

Mental fatigue in day school children as measured by arithmetical reasoning, B. J. P., IV, 1911, 315.

Wright, W. R., *Some effects of incentives on work and fatigue*, P. R., XIII, 1906, 23.

Yoakum, C. S., *An experimental study of fatigue*, P. R. Mon. Sup., No. 46, 1909.

CHAPTER XIII.

INBORN NATURE IN RELATION TO LEARNING.

Habits and knowledge are the results of established bonds, instincts are the result of inherited bonds. In the strict sense, an instinct is a response connected to its stimulus by an inherited neural bond. This inherited bond may have all degrees of definiteness, from zero on the one hand to absolute definiteness on the other. It is our purpose in this chapter to enquire into the relationship between the inherited bonds and the acquired bonds, particularly into the use that can be made of the instincts and emotions in the work of forming habits and acquiring knowledge.

In the first place it is necessary to correct an erroneous notion in regard to the instincts. Some writers state that the instincts are the basis of all our acquirements, that every habit is merely the modification of some instinct. This is not true. We are born with a nervous system with some differences in resistance to various types of stimuli already established. But any conceivable connection of stimuli with responses is possible. We have the nerves. They go on the one hand to sense organs; on the other, to muscles. The stimulus-response couplings that are possible are practically infinite, regardless of the inherited couplings. Not only are inherited bonds not the basis of all acquirements, but we can overcome and reverse inherited differential resistances. The inherited bonds are colorless or indif-

ferent to most of our acquirements. For example, language, saying the multiplication table, playing a piano, are in no sense modifications of instincts. Some children learn to call a certain animal a "dog"; others, learn to call it "ein Hund"; the ancient Roman called it "canis." And we could just as well learn to call it anything else, for there is no inherited bias in the matter. In playing the piano, the position of the notes on the staff determine what piano key we shall strike. It is of course absurd to believe that there is any inherited bias for striking one key for a certain note rather than some other key. The part which the instincts play in our learning is other than forming the basis of our acquirements.

Imitation.—Imitation is not an instinct in the strict sense. If it were, then the perception of an act would, without training, be an adequate stimulus for the act. But such is not the case. However, the tendency to imitate, the desire which children have to do what they see others do, is an inborn human characteristic. This tendency is universal in the human race, and from the point of view of education, is one of the most important of all human traits. The tendency to do what is seen done probably has more to do in leading a child to a mastery of the world which immediately surrounds him than any other single factor with the possible exception of play. One has only to observe children in the home to be convinced of the importance of imitation. The little girl wants to do and tries to do all that she sees her mother do. She attempts to do all that she sees done. The acts which she thus attempts, she can not perform at first, unless these acts have already been mastered in some other connection, but she tries to do

them, and she keeps on trying till they are mastered. As a rule, when such an act is mastered, it loses its attraction, and the child passes on to the mastery of some other perceived action. The result is mastery of all the mother does; and in acquiring this mastery, the girl has learned a great many things about the world. The case is similar with the boy, only his world is larger. In mastering what he sees his father and other older people do, he not only learns to do many different things, but learns much about the world in all its varied aspects. He learns much about forces and energy, the principles of machines, etc. One can hardly overestimate the importance which imitation has in adjusting and adapting the child to the physical and social world. Through imitation, children acquire their language, manners and customs, traditions, morals, religion, and their attitude toward nearly all important aspects of life. It is doubtful whether any other factor is so important in developing habits of honesty, industry, perseverance, and the various important ideals of life and character.

Imitation in School Work.—Imitation can be used in school as a method of mastering mechanical processes, such as arithmetical processes, writing, drawing, and music. The first step in the process of habit-formation should be demonstration by the teacher. When any new process is taken up, say long division, the teacher should demonstrate clearly every step in the process. This is a matter of economy. Such a procedure leads to quick mastery. The child should not have originality in formal processes. He needs merely to master them and do them as older people do them, and master them

in the quickest possible way. To imitate the performance of the teacher is the quickest way.

Imitation and Ideals.—During the high school period, which covers roughly the period of adolescence, boys and girls acquire what, in most cases, prove to be their final life ideals. These ideals are copied from the acts of their fellows, primarily from their elders, and from the acts which they read about in literature and history. It seems probable that the attitudes and ideals which adolescents acquire are of far more importance to their lives afterward than all the facts they acquire during this period. If this is true, and the author believes it is, then the influences which the school, home and all the other social forces bring to bear to develop these ideals and attitudes, are of more importance than the ordinary formal high school curriculum. The actual amount of the content of the high school curriculum that gets into the life of the boys and girls, and becomes an important factor there, is doubtless small, but there can be no doubt of the profound influence on their lives of the moulding of character that goes on during this period. The character-formation of these years is crucial and determining for the future. All educational forces that concern this period should take these facts into account. In careful, scientific fashion the sources of adolescent ideals should be determined and measured. Of great use here is literature. The high school teacher of literature has great things within her power. The whole literature of the world, of all ages and all countries, should be studied with reference to its value in bringing before adolescents the highest ideals of action. In spite of apparent indications to the contrary, adolescents are teachable, susceptible, easily swayed one way

or another. The teachings of the world's great teachers should be brought before them. Under the sympathetic guidance of teachers and parents these forces mould the character of the boy and girl.

Imitation in Adult Life.—Imitation is an important factor not only in the lives of children, but in the lives of men and women. Throughout adult life, imitation is one of the great social forces. In childhood, as shown above, we become adapted and adjusted largely through the process of imitation. As long as we live imitation holds us to the forms to which we have become accustomed. Of course, other factors are also at work, the desire of public approval and the fear of public condemnation. These three forces are the whip which makes us conform, makes each do what all the others are doing. What others are wearing, I must wear; what others are saying, I must say; what others are doing, I must do; what others are learning, I must learn; what others are thinking, I must think. The press comes to the aid of conformity. We read the same newspaper at breakfast, the same magazine after supper, the same "best seller" at the week-end. Education itself is a great force for conformity. Education is conservative; it moulds us in the same mould. It must necessarily be organised and systematised. In the process there is a danger that the child will lose originality and initiative. Organisation and systematisation are but means to an end. The end is the teaching of children. The machinery of education has its proper function, and principals and superintendents who direct the machinery have their proper functions, namely to secure all those conditions that will enable the best teachers to do their work in the best way. We must

not, however, lose sight of the fact that the final goal which all must strive to reach is good teaching. The school must preserve a proper balance between conservatism and progress. While the school is an institution of society one of whose great functions has been to hand down to a new generation that which the old generations thought good, it must also be a means of progress by encouraging and stimulating individuality. In impressing the past on the young, we must not destroy the future. Imitation is the aspect of inborn nature which makes possible the great influence which the old generation has upon the new. But there are also in human nature inborn tendencies which work for variation and individuality. The wise teacher will seek a proper balance between the two sets of tendencies. There must be a certain degree of conformity if we are to live together with any considerable contentment and happiness, but the conformity must not be such as to destroy all initiative, individuality, and progress.

Rivalry and Learning.—One of the oldest and strongest inherited tendencies in man is the tendency to fight. For ages unnumbered, our ancestors have been fighters. Each human individual has had to look out for himself. Natural selection has picked out the fighter. Our ancestors were those who overcame their adversaries. Man's progress has been one great fight. Every step has been marked in blood. As a result of the constant action of natural selection, there have been established in us many strong inherited tendencies connected with individual survival, that may be called the individualistic instincts. Examples of these instincts are the acts connected with rivalry, competition, fighting, and with the emotions of anger, envy, and jealousy. The stimuli

that evoke these various tendencies and responses are attacks upon ourselves. This attack may be an actual physical attack upon our person, or a threatened attack. It may, however, be merely a verbal attack upon our belief, or our looks, or our friend or relative. Whatever the nature of the attack, the physiological response is much the same. There are characteristic changes in the heart-beat, circulation, respiration, and in various other muscles and organs. A strong emotion is aroused, as anger, or envy, or jealousy.

When children start to school no tendency is stronger or more marked than individualistic tendencies. The self is then the biggest thing in the world. Children are constantly measuring themselves with one another. They not only compare their personal selves but everything that belongs to them, their parents, their homes, their clothes. I have heard children boast of how many times they had been to the dentist! Eternal competition is the rule of child life, as it has been the rule of all life, all business, all trade, in fact almost everything in the life of man. What should be the attitude of the teacher toward this characteristic of childhood? We can not get rid of it. It permeates almost every fibre in the structure of life, and every work and institution of man. We must take it into account if we are going to deal with human nature because it is a large part of human nature. Fortunately it has its good aspect. Self respect depends upon this aspect of our nature. When a person has no fight in him, he is just about hopeless. As society and human nature are now constituted, we must make a limited use of competition in learning. The desire to excel must continue to be a motive. But the use we make of rivalry and competition must be

limited. As the child grows older we can develop other motives. We can create desire for things in themselves, desire for absolute good, apart from what others may have. Education must certainly take this attitude, for nearly all the pain and sorrow and trouble in the world are due to some aspect of selfishness. This selfishness is in human nature, it is true, but our only hope for any sort of decent life consists in suppressing certain aspects of selfishness, and in developing sympathy and co-operation. The hope of the world lies in building school houses rather than battleships. As long as peace is maintained by the sword, it is not peace, it is merely a truce.

Roving and Collecting Tendencies.—Man's wild life in the past has left him with two tendencies which are educational assets. The child, by nature, dislikes confinement, restriction of liberty, and likes freedom. Children like to be going, to see new things, to have new experiences in other places. A closely related tendency is collecting. A child, by nature, picks up and takes along with him everything that attracts attention and is loose. Education can profit greatly from both these tendencies. Part of the work of education is learning the world. The world is, for the most part, outside of the school house. The child must go out to study it. The river, the mountain, the animals, the plants, nearly all the world, is outside, and the child must go out to study it. He can bring back to school not only a report but specimens. From the specimens should be made a school museum, which should be a reproduction of the world outside.

Play and Education.—From the point of view of education, imitation and play are the most important

aspects of child life for they lead to nearly all acquirements. The importance of imitation has already been pointed out. Play is the spontaneous activity of the individual. It is doing what we want to do, it is the expression of our inmost desires, our most real self. Play activities are those intrinsically pleasurable, those which we seek for the pleasure which they give and not for any good that results. The child learns most successfully when his practice has in it the spirit of play. This is at once evident to us when we remember what was said in preceding chapters about attention and interest. We learn best when we are attentive and when the learning or its result is pleasurable. To put it in another way: we learn best when we put our whole self into the learning. In no other activities are these conditions so well met as in play activities. But it is not always easy to realise these conditions. We who are old set the tasks for those who are young. We know what is best for the young to learn. We put them to work to do what we impose upon them. One is not likely to put forth all his energy except in a self-imposed task. The learning of children will progress at a much faster rate if we can enlist their native desires and their own ambitions. Many helpful improvements can be made in this direction. Goals and objectives can be selected that are near instead of remote. While the ultimate end of education is adult efficiency, closer ends can always be made out. A child can not be expected to work on indefinitely in the mere hope that some time, somewhere, he will reap some return for his labors. In a large measure a child's present needs can be used as incentives which lead to performances that prepare for later life. About all this amounts to is this: In as far

as possible, we are to make appeal to the child's native equipment, native desires, and native ambitions. The danger is that the teacher, in making this appeal, will go to an extreme that will cause education to lose more than it gains. While we learn best when we do what we want to do, an education that permits the child to do only what it wants to do is no education at all. For life is such and this world is such that we all have to do many hard things, many disagreeable things. No one ever amounts to anything who has not learned to do what is hard, who has not learned to stick to a task undertaken. No use of play should be made in education that in any way hinders us in giving the child a discipline and a training that will lead to worthwhile achievement. The proper solution of the problem consists in leading the child to form ambitions and aims and desires in the attainment of which he is willing to work to the uttermost. After all, we never succeed in education until our aims have become the child's aims, until our purposes have become his purposes.

Manipulation.—A native tendency that is of use in early education and all later education as well, is that of manipulation. The child, by virtue of its inborn nature, wishes to touch, handle, manipulate all that it sees. In the early years of infancy this tendency leads the child to a mastery of many things in its environment. Of course, it is a rather expensive tendency, and parents usually suppress it in the interest of preserving the furniture and other household implements, such as clocks, sewing machines and door bells. In suppressing this tendency, parents kill or partially kill one of the most important characteristics of human nature. True and accurate knowledge comes only from contact with

things, only from manipulation. But in opposition to all that is natural, we take the child to school, put it into a seat, tell it to keep its hands off of things, *and give it a book.* As a result, the child's education is a sort of second hand education, one or more steps removed from reality. The proper procedure would be to use in every step of education the inborn tendency to manipulate. In getting a knowledge of the world, the child should manipulate the various objects of the world.

The Emotions and Learning.—Our discussion of the inborn nature of children leads us finally to a consideration of the emotions and their relation to learning. Our emotions are the most intimate parts of us; they are back of nearly all that we voluntarily do. At the bottom of nearly every act is love, or hate, or envy, or jealousy, or anger, or fear. Nothing of very great consequence is ever undertaken that does not have back of it some emotion. The great teacher is he who has a profound understanding of human life, and knows how to mould and change it; knows how to use what he finds as a means of making the child different.

In the preceding chapters of this book we have discussed many factors and elements of learning, we have tried to find the most economical ways of learning. And this is well for we must use every known means to facilitate learning. But no factor is of more significance than the emotions. It is worth while that a child practice for the proper length of period at whatever he is trying to learn, but unless he is in the proper emotional attitude it does not make much difference whether he practice at all. The great teacher is he who can profoundly influence the child, who can inspire, and

command respect and reverence. The teacher is not merely to find out what the child wants and help him to attain his wants, but should change the wants. The child is to be changed into a being that wants the higher things. What gives us pleasure is in a large measure the result of experience and training. It is the business of the teacher to train the child to get pleasure from the higher things of eternal value. All knowledge, all habits are merely a means. The end is the satisfaction of the higher nature of man. The teacher in the detail of teaching geography, or arithmetic, or history, should always have in mind the higher aim of education as a whole; should always remember that education is to lead to knowledge, and habits, and ideals that are the means of living a life that is worthy of man.

EXPERIMENTS AND EXERCISES.

1. Make a rough study of the effects of emotion on learning by learning nonsense syllables under different emotional conditions. Within the course of a few weeks, oportunity for the different experiments may be offered.
2. Make a study of the different treatises of instincts, such as are found in Kirkpatrick's Fundamentals of Child Study or the author's Outlines of Educational Psychology, and select all those aspects of original nature that can be used in learning.

REFERENCES.

Barnes, E., *Studies in education,* Vol. I, 1896, Children's Collections, p. 144.

Burk, C. F., *The collecting instinct,* Ped. Sem. VII, 1900, 179.

Carver, A., *The generation and control of emotions,* B. J. P., X, 1919, 51.

Dearborn, G. V. N., *The influence of joy,* 1916.

Hall, G. S., *A Study of anger,* A. J. P., X, 1898-99, 516.

Henry, T. S., *The education and control of emotions*, J. E. P., VIII, 1917, 407.

Hunter, W. S., *The modification of instinct from the standpoint of social phychology*, P. R., XXVII, 1920, 247.

Johnson, G. E., *Education by plays and games*, 1907.

Kantor, J. R., *A functional interpretation of human instincts*, P. R., XXVII, 1920, 50.

Kline, L. W., *Truancy as related to the migrating instinct*, Ped. Sem., V, 1897-98, 381.

The migratory impulse vs. love of home, A. J. P., X, 1898-99, 1.

Martin, L. J., *The training of emotion*, 1918.

Ordahl, G., *Rivalry, its genetic development and pedagogy*, Ped. Sem., XV, 1908, 492.

Richardson, R. F., *The psychology and pedagogy of anger*, Ed. Psych. Mon., No. 19, 1918.

Saxby, I. B., *Some conditions affecting the growth and permanence of desire*, B. J. P., IX, 1917, 93.

Tolman, E. C., *Instinct and purpose*, P. R., XXVII, 1920, 217.

For fuller treatment of the instincts and for more extensive references, see the chapters on the instincts in the author's Outlines of educational psychology.

CHAPTER XIV.

MEASURES.

Central Tendency.—After measuring the learning capacity of a group of students, we must have some method of expressing and interpreting the results. The first important determination is the central tendency. There are three commonly used measures of central tendency, the average, the median, and the mode. To find the average, we simply add the scores made by the various individuals tested and divide the sum by the number of cases. The median is the middle measure. To find the median it is necessary to rank the subjects tested on the basis of efficiency in the test, giving the person making the highest score the rank 1; the next highest, the rank 2; the next highest, the rank 3, and so on to the poorest. We then find that rank that has as many ranks above it as below it. The score which this rank represents is the median score. It often happens that the median represents no actual score, as when the number of cases is an even number, and when the median falls within a group of cases having the same score. In such cases, the median must be calculated as shown in the illustration.

The three measures of central tendency may be illustrated from the following data, which represent the speed in seconds attained by each of 64 university students, sorting 25 cards into five boxes. The numbers

given represent the 12th score. The actual scores were as follows: 20, 19, 21, 11, 19, 16, 17, 21, 19, 27, 16, 15, 13, 16, 21, 16, 15, 20, 22, 17, 16, 22, 15, 20, 15, 17, 18, 22, 18, 16, 20, 15, 17, 25, 20, 16, 19, 20, 22, 17, 25, 16, 20, 24, 24, 21, 21, 22, 24, 19, 16, 13, 21, 24, 18, 18, 19, 16, 15, 16, 18, 20, 15, 13.

Score in Seconds.	Number of Cases.	Sum.
11	1	......
13	3	......
15	7	......
16	11	......
17	5	......
18	5	32
19	6	32
20	8	......
21	6	......
22	5	......
24	4	......
25	2	......
27	1	......

The sum of the scores is 1189; the number of cases is 64. 1189÷64=18.56, the average. By arranging the scores as shown in the accompanying table, it can be seen that 32 scores are 18 seconds or less, and that 32 cases are 19 seconds or more. The median therefore lies midway between 18 and 19, and is 18.5 seconds. Suppose we omit the slowest person, whose time was 27 seconds, and find the median of the 63 remaining scores. There are 31 scores of 19 seconds and slower and 32 scores of 18 and faster. The median lies in the group of five making a score of 18 seconds. In such a case we find the percentage of this group that must be added or subtracted to make the number of cases equal, and add or subtract, according to which way we are counting, this percentage to the last score preceding

the score of the group in which the median lies. The number of scores up to and including 17 seconds is 27. Half the number of scores is 31½. 31½—27=4½. There are 5 scores in the group 18. 4½ is .9 of 5. We therefore add .9 to 17, which gives a median of 17.9.

The mode is the most frequent measure. Reference to the table shows that 16 seconds is the mode.

Measures of Variability.—After we have measured the central tendency of a group, we need to know the variability, i. e., how much the members of the group vary from the central tendency. There are three common measures of variability, the average deviation, the standard deviation, and the probable error. The average deviation is simply the average amount of deviation from the central tendency. It is found by finding each individual's deviation from the central tendency, adding these amounts without regard to whether they are positive or negative, and dividing by the number of cases. The standard deviation is the square root of the average of the squares of the individual deviations. The probable error is that measure above and below the central tendency that includes half the cases. All of these measures can be illustrated from the scores from card-sorting given above. For computing them, it is customary to use either the median or the average as the measure of the central tendency. We shall use the measure 18.5, which is practically both the median and the average. In the table are shown the individual scores, the deviations, the squares of the individual deviations.

Score	d	d^2	22	3.5	12.25	24	5.5	30.25
20	1.5	2.25	15	3.5	12.25	24	5.5	30.25
19	.5	.25	20	1.5	2.25	21	2.5	6.25
21	2.5	6.25	15	3.5	12.25	21	2.5	6.25
11	7.5	56.25	17	1.5	2.25	22	3.5	12.25
19	.5	.25	18	.5	.25	24	5.5	30.25
16	2.5	6.25	22	3.5	12.25	19	.5	.25
17	1.5	2.25	18	.5	.25	16	2.5	6.25
21	2.5	6.25	16	2.5	6.25	13	5.5	30.25
19	.5	.25	20	1.5	2.25	21	2.5	6.25
27	8.5	72.25	15	3.5	12.25	24	5.5	30.25
16	2.5	6.25	17	1.5	2.25	18	.5	.25
15	3.5	12.25	25	6.5	42.25	18	.5	.25
13	5.5	30.25	20	1.5	2.25	19	1.5	2.25
16	2.5	6.25	16	2.5	6.25	16	2.5	6.25
21	2.5	6.25	19	.5	.25	15	3.5	12.25
16	2.5	6.25	20	1.5	2.25	16	2.5	6.25
15	3.5	12.25	22	3.5	12.25	18	.5	.25
20	1.5	2.25	17	1.5	2.25	20	1.5	2.25
22	3.5	12.25	25	6.5	42.25	15	3.5	12.25
17	1.5	2.25	16	2.5	6.25	13	5.5	30.25
16	2.5	6.25	20	1.5	2.25			
						Sum	179.0	712.00

The sum of the individual deviations is 179. $179 \div 64 = 2.8$, A. D. The sum of the squares of the individual deviations is 712. $712 \div 64 = 11.12$. The square root of $11.12 = 3.3$, the S. D. or σ.

To determine the probable error, we count back each way from the average or median till we have 32 cases. Taking two seconds above and below gives us 24 cases. In the 16-second group are 11 cases, and in the 21-second group are 6 cases. In the two groups are 17 cases. Only eight of them can be counted to make up the required 32. Eight is .47 of 17, the probable error is therefore 2.47 seconds. In a normal distribution, the probable error is .6745 of the standard deviation. If the scores were distributed in accordance with the normal frequency curve, the probable error would be .6745 of 3.3, or 2.23.

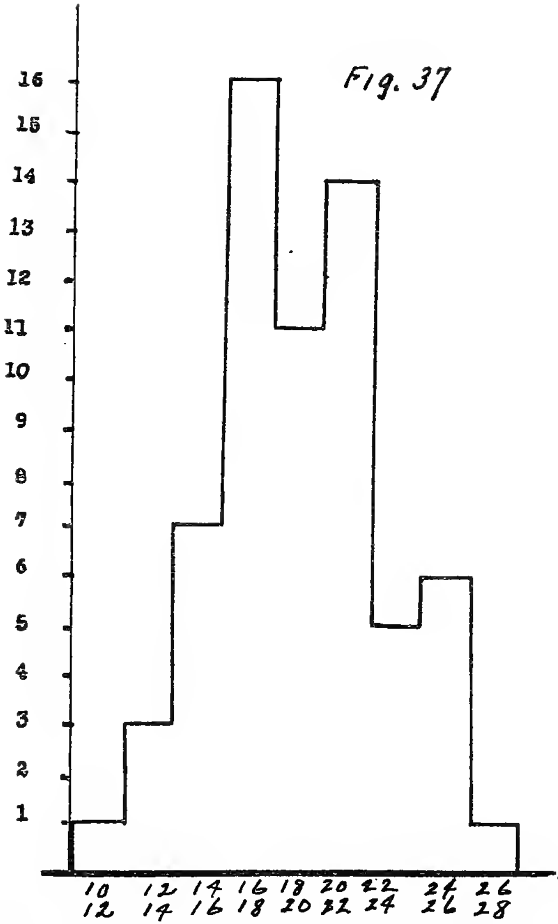

FIGURE 37. FREQUENCY SURFACE OR CURVE OF DISTRIBUTION. The scores are represented on the horizontal axis, and the number of subjects making the respective scores, on the vertical axis.

The relationships among the different measures of variability are as follows:

S. D.=1.2533 A D., 1.4825 P. E.

P. E.= .6745 S. D., .8453 A. D.

A. D.=1.1843 P. E., .7979 S. D.

Frequency Surfaces. — The frequency surface or curve of distribution is a graphical means of representing the distribution of a group with reference to some measure. The distribution of the scores given above is shown in Figure 37, constructed as follows: We determine the number of cases included in the 10 and 11 minute groups, the 12 and 13 minute groups, the 14 and 15 minute groups, and so on. The scores are represented on the horizontal axis and the number of cases for each score, on the vertical axis. We arbitrarily select some unit to represent one case, and then simply take those distances above the base that represent the several numbers of cases. The score-groups with their respective numbers of cases are as follows: 10-11, 1; 12-13, 3; 14-15, 7; 16-17, 16; 18-19, 11; 20-21,

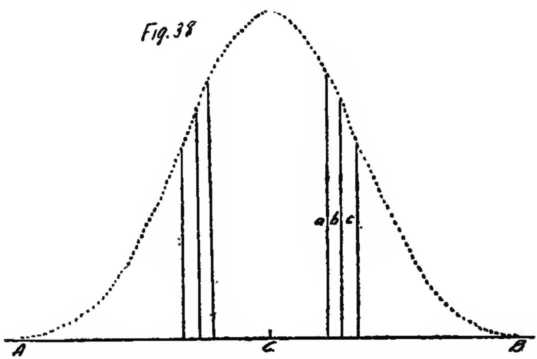

FIGURE 38. NORMAL FREQUENCY CURVE. a=the probable error; b=the ahe average deviation; c=the standard deviation.

14; 22-23, 5; 24-25, 6; 26-27, 1. A normal distribution or symmetrical curve is shown in Fig. 38. Human traits are probably distributed in accordance with the normal curve, and in measuring human traits, if we have a large number of cases, we may expect our results to approximate the normal curve.

Correlation.—By correlation we mean the relation that exists between two functions. For example, suppose we have measured the several abilities of the members of a group in one kind of learning and wish to compare those abilities with the corresponding abilities in another kind of learning, we resort to the correlation formula. In a small group, mere inspection of the results of the experiments would enable us to make a rough comparison of the two different functions, but from mere inspection we could not make an accurate quantitative statement. There are several formulas for computing correlation. The one in more general use is the Pearson formula, $r = \frac{\Sigma XY}{n\,\sigma_1\,\sigma_2}$, in which

r=correlation,
Σ=the algebraic sum of
X=the individual deviations in one function,
Y=the individual deviations in the other function,
n=the number of cases,
σ_1=the standard deviation in one function,
σ_2=the standard deviation in the other function.

We give below an illustrative problem. In column one are given the scores of a group of 15 students in visual substance learning, in column 4 are given their corresponding scores in visual verbatim learning.

1	2	3	4	5	6	7	8
41	— 9	81	44	— 6	36	54	......
36	—14	196	35	—15	225	210	......
48	— 2	4	53	+ 3	9	......	— 6
52	+ 2	4	57	+ 7	49	14	......
64	+14	196	61	+11	121	154	......
62	+12	144	62	+12	144	144	......
60	+10	100	62	+12	144	120	......
62	+12	144	52	+ 2	4	24	......
54	+ 4	16	51	+ 1	1	4	......
47	— 3	9	30	—20	400	60	......
45	— 5	25	27	—23	529	115	......
39	—11	121	61	+11	121	......	—121
51	+ 1	1	56	+ 6	36	6	......
47	— 3	9	55	+ 5	25	......	— 15
45	— 5	25	45	— 5	25	25	......
		1075			1869	930	142

The scores are shown in columns 1 and 4, the deviations in columns 2 and 5, the squares of the deviations in columns 3 and 6, the plus products are shown in column 7 and the minus products in column 8. The standard deviation for the first column is $\sqrt{\dfrac{1075}{15}}=8.46$.

The standard deviation for column 4 is $\sqrt{\dfrac{1869}{15}}=11.16$.

The numerator of the fraction in the Pearson formula is the algebraic sum of the products of the individual deviations. The sum of the plus products as shown in column 7 is 930. The sum of the minus products as shown in column 8 is 142. 930—142=788. We then have

$$r=\frac{788}{15\times8.46\times11.16}=.556.$$

A simple method of computing correlation by using rank differences instead of the absolute deviation is what is known as Spearman's "Foot-Rule" formula:

$$R = 1 - \frac{6\Sigma g}{n^2 - 1},$$

in which R=correlation,

Σ=the sum of

g=an individual's gain in rank in the second function over the rank in the first function,

n=the number of cases.

The Spearman formula gives a lower correlation than the Pearson formula.

The procedure in using the Spearman formula is as follows: Rank the subjects with reference to standing in one function, then find their corresponding ranks in the other function. The gains in rank are then added and multiplied by 6. This product is the numerator of the fraction. The denominator is one less than the square of the number of cases. The fraction converted into decimal form is subtracted from 1. The result is the correlation. The result is not so accurate as that obtained from the Pearson formula because no account is taken of the absolute amount of individual differences. It is a useful formula for rough determination of correlation when there are only a few cases.

The use of the Spearman formula is illustrated in the following example from the same data used in illustrating the Pearson formula. In the first and third columns are given the scores in the two functions. In the second column are the ranks in the first function, and in the fourth column are the ranks for the second function. In the fifth column are indicated the gains in rank.

1	2	3	4	5
64	1	61	3.5	......
62	2.5	62	1.5	1.0
62	2.5	52	9	......
60	4	62	1.5	2.5
54	5	51	10	......
52	6	57	5	1
51	7	56	6	1
48	8	53	8	......
47	9.5	30	14	......
47	9.5	55	7	2.5
45	11.5	45	11	.5
45	11.5	27	15	......
41	13	44	12	1
39	14	61	3.5	10.5
36	15	35	13	2

Sum of gains=22

$$1-\frac{6\times 22}{224}=.41=R.$$

N=15, $N^2=225$, $N^2-1=224$.

Probable Error of Correlation.—The formula for determining the probable error of correlation is,

$$P.\ E.=.6745\ \frac{1-r^2}{\sqrt{n}}$$

In the illustration of the Pearson formula above, the correlation was found to be .556. $(.556)^2=.309136$.

1—.309136=.690864,

$\sqrt{15}=3.87$,

.690864÷3.87=.18=P. E.

A correlation is not of much significance unless it is at least three times its P. E.

Conversion of Grades and Scores.—It often happens that we wish to convert scores or grades made in different experiments or different subjects to the same basis for purpose of comparison, or to be able to add the scores and give a single rating for all the scores

combined. The object of reducing to the same basis is to be able to give the same weight to the different measures. For example: Suppose we have given a number of different mental tests to students and wish to express in one number their respective abilities. If we simply add the scores more weight is given to those scores that have a high average, but if we reduce the scores in each test to a common average, each test has the same weight in this average. It makes no difference what average is chosen, but 50 is a convenient number. The process of conversion is as follows: Find the average in each test, and then give each subject a score that has the same ratio to his actual score that 50 has to the actual average. By the use of a slide rule this conversion can be quickly and accurately done. In tests that have a work limit, efficiency depending upon time required to do the work, a low score means high efficiency. In such cases, first determine the reciprocals of each score by means of a slide rule or by using tables, such as Barlow's, then make the conversion as explained above.

REFERENCES.

Rugg, H. O., *Statistical Methods Applied to Education*, 1917.

Thorndike, E. L., *Mental and Social Measurements*, 1904, especially Chs. 4, 5, 6 and 9.

Whipple, G. M., *Manual of Mental and Physical Tests*, 1915 especially Ch. 3.

BIBLIOGRAPHY

Explanation of abbreviations.—A. J. P., *American Journal of Psychology*; Arch. of Psych., *Archives of Psychology;* B. J. P., *British Journal of Psychology;* Ed. Rev., *Educational Review:* J. E. P., *Journal of Educational Psychology;* J. Exp. Psych., *Journal of Experimental Psychology;* Ped. Sem., *Pedagogical Seminary;* P. R., *Psychological Review;* P. R. Mon. Sup., *Psychological Review Monograph Supplement;* P. R. Mon., *Psychological Review Monograph;* S. and S., *School and Society; T. C. Cont. to Ed. Teachers' College Columbia University Contributions to Education.*

Aikens. H. A., and Thorndike, E. L., *Correlations in the perceptive and associative processes*, P. R., IX, 1902, 374.

Arps, G. F., *A Preliminary report on work with knowledge vs. work without knowledge of results*, P. R., XXIV, 1917, 449.

Ash, I. E., *Fatigue and its effects upon control*, Arch. of Psych., IV, 1914, No. 31.

Bagley, W. C. and Squire, C. R., *Experiments on transfer of ideals of neatness*, Educational Values, 1905, 188.

Bair, J. H., *The Practice curve*, P. R. Mon. Sup. No. 19, 1902.

Barnes, E., *Studies in education*, Vol. I, 1896-7, 144.

Bean, C. H., *The curve of forgetting*, Arch. of Psych., XX, No. 3, 1912.

Bennett, F., *The correlation between different memories*, J. Exp. Psych., I, 1916, 404.

Bergstrom, J. A., *Experiments upon physiological memory by means of the interference of associations*, A. J. P. V., 1893, 356.

The relation of the interference to the practice effect of an association, A. J. P., VI, 1894, 433.

Bonser, F. G., *The selective significance of reasoning ability tests*, J. E. P., VII, 1916, 187.

Book, W. F., *The rôle of the teacher in the most expeditious and economic learning*, J. E. P., I, 1910, 183.

Boswell, F. P. and Foster, W. S., *On memorising with the intention permanently to retain*, A. J. P., XXVII, 1916, 420.

Bradford, C. J., *An experiment in typewriting*, Ped. Sem., XXII, 1915, 445.

Brown, D. E., Browning, M. and Washburn, M. F., *The effect of the interval between repetitions on the speed of learning a series of movements*, A. J. P., XXIV, 1913, 580.

Brown, J. C., *An investigation on the value of drill work in*

fundamental operations of arithmetic, J. E. P., II, 1911, 81, also III, 1912, 485, 561.

Brown, W., *Some experimental results in the correlation of mental abilities*, B. J. P., III, 1910, 296.

Mental measurement, 1911.

Practice in associating color-names with colors. P. R., XXII, 1915, 45.

Practice in associating number names with number symbols, P. R., XXII, 1915, 77.

Bryan, W. L. and Harter, Noble, *Studies on the telegraphic language; the acquistion of a hierarchy of habits*, P. R., VI, 1899, 346.

Burk, C. F., *The collecting instinct*, Ped. Sem., VII, 1900, 179.

Burnham, W. H., *Oxygen supply as a condition of efficient brain activity*, J. E. P., II, 1911, 421.

The hygiene of sleep, Ped. Sem., XXVII, 1920, 1.

Burt, C., *Experimental tests of general intelligence*, B. J. P. III, 1908, 94.

Carver, A., *The generation and control of emotions*, B. J. P., X, 1919, 51.

Chamberlain, A. H., *A memory test with school children*, P. R., XXII, 1915, 71.

Chapman, J. C., *Individual differences, in ability and improvement and their correlations*, T. C. Cont. to Ed., No. 63.

Chapman, J. C. and Nolan, W. J., *Initial spurt in a simple mental function*, A. J. P., XXVII, 1916, 256.

Chapman, J. C. and Feder, R. B., *The effect of external incentives on improvement*, J. E. P., VIII, 1917, 469.

Cogan, L. G. and Conklin, A. M. and Hollingworth, H. L., *An experimental study of self analysis, estimates of associates and psychological tests*, S. and S., II, 1915, 171.

Conrad, H. E. and Arps, G. F., *An experimental study of economical learning*, A. J. P., XXVII, 1916, 507.

Coover, J. E. and Angell, F., *General practice effects of special exercise*, A. J. P., XVIII, 1907, 328.

Cowan, E. A., *An experiment on the influence of training on memory*, J. E. P., VII, 1916, 31.

Culler, A. J., *Interference and adaptability*, Arch. Psych., No. 24, 1912.

Cummins, R. A., *A study of the effect of basket-ball practice on motor reaction, attention and suggestibility*, P. R., XXI, 1914, 356.

Improvement and the distribution of practice. T. C. Cont. to Ed., No. 97, 1919.

Dallenbach, K. M., *The effect of practice on visual apprehension in school children*, J. E. P., V, 1914, 321, 387.

The effect of practice upon visual apprehension in the feebleminded, J. E. P., X, 1919, 61.

Dashiell, J. F., *The effects of practice upon two mental tests*, J. E. P., XI, 1920, 151.

A comparison of complete vs. alternate methods of learning two habits, P. R., XXVII, 1920, 112.

Dearborn, G. V. N., *The influence of joy*, 1916.

Dearborn, W. F., *The general effects of special practice in memory*, P. Bul., VI, 1909, 44.

Dell, J. A., *Some observations on the learning of sensible material*, J. E. P., III, 1912, 401.

Dewey, J., *How we think*, 1910.

Dodge, R., *The laws of relative fatigue*, P. R., XXIV, 1917, 89.

Donovan, M. E. and Thorndike, E. L., *Improvement in a practice experiment under school conditions*, A. J. P., XXIV, 1913, 426.

Downey, J. E. and Anderson, J. E., *Retension of skill after lapse of practicc*, A. J. P., XXVIII, 1917, 396.

Dunlap, K., *The biological basis of the association of ideas and the development of perception*, Psychobiology, II, 1920, 29.

Experiments in learning, J. E. P., I, 1910, 373.

Ebbinghaus, H., *Memory*, 1885, Tr. by H. A. Ruger, 1913.

Ebert, E. and Meumann, E., *Ueber einige Grundfragen der Psychologie der Uebungsphänomene im Bereiche des Gedächtnisses*, Arch. f. d. gesamte Psych., IV, 1904, 1.

Elderton, E. M., *On the association of drawing with other capacities in school children, Biometrica*, 1909-10, III, 222.

Evans, J. E., *The effect of distraction on reaction time with special reference to practice and the transfer of training*, Arch. of Psych., No. 37, 1916.

Finkenbinder, E. O., *The curve of forgetting*, A. J. P., XXIV, 1913, 8.

Fracker, G. C., *On the transference of training in memory*, P. R. Mon. Sup., No. 38, 1908, 56.

Fulton, M. J., *An experiment in teaching spelling*, Ped. Sem., XXI, 1914, 287.

Garth, T. R., *Mental fatigue*, Arch. of Psych., No. 41, 1918.

Gates, A. I., *Diurnal variations in memory and association*, Univ. of Cal. Pub. in Psych., I, No. 5, 1916, 323.

Experiments on the relative efficiency of men and women in memory and reasoning, P. R., XXIV, 1917, 139.

Recitation as a factor in memorising, Arch. of Psych., No. 40, 1917.

Correlation of immediate and delayed recall, J. E. P., IX, 1918, 489.

The mnemonic span for visual and auditory digits, J. Exp. Psych., I, 1916, 393.

Gates, A. I., *Variations in efficiency during the day, together with practice effects, sex differences, and correlations*, Univ. of Cal. Pub. in Psych., II, No. 1, 1916.

Gilbert, J. A. and Fracker, G. C., *The effects of practice in reaction and discrimination for sound upon the time of reaction and discrimination of other forms of stimuli*, Univ. of Iowa Studies in Psych., I, 1897, 62.

Gray, T. C., *A comparison of two types of learning by means of a substitution test*, J. E. P., IX, 1918, 143.

Guillet, C., *Retentiveness in child and adult*, A. J. P., XX, 1909, 318.

A study of memory of young women, J. E. P., VIII, 1917, 65.

Haggerty, M. E., *The laws of learning*, P. R., XX, 1913, 411.

Hall, G. S., *Note on early memories*, Ped. Sem., VI, 1899, 485.

A study of anger, A. J. P., X, 1898-9, 516.

Some psychological aspects of language teaching, Ped. Sem., XXI, 1914, 256.

Hart, B. and Spearman, C., *General ability, its existence and nature*, B. J. P., V, 1912, 51.

Hawkins, C. J., *Experiments on memory types*, P. R., IV, 1897, 289.

Hayden, E. A., *Memory for lifted weights*, A. J. P., XVII, 1906. 497.

Heck, W. H., *A study of mental fatigue*, 1913.

Henmon, V. A. C., *The relation between mode of presentation and retention*, P. R., XIX, 1912, 79.

The relation between learning and retention and amount to be learned, J. Exp. Psych., II, 1917, 476.

Henry T. S., *The education and control of emotions*, J. E. P., VIII, 1917, 407.

Hewins, N. P., *The doctrine of formal discipline in the light of experimental investigation*, 1916.

Hill, D. S., *Minor studies in learning and relearning*, J. E. P., V, 1914, 375.

Hollingworth, H. L.. *Variations in effiiciency during the working day*, P. R., XXI, 1914, 473.

Characteristic differences between recall and recognition. A. J. P., XXIV, 1913, 532.

Correlation of abilities as affected by practice, J. E. P., IV, 1913, 405.

Individual differences before, during and after practice, P. R., XXI, 1914, 1.

Hunter, W. S., *The modification of instinct from the standpoint of social psychology*. P. R., XXVII, 1920. 247.

Johnson, G. E., *Education by plays and games*, 1907.

Judd, C. H., *The relation of special training to general intelligence*, Ed. Rev., XXXVI, 1908, 28.

Practice and its effects on the perception of illusions, P. R., IX, 1902, 27.

The psychology of high school subjects, 1915, Ch. 17.

Kennedy, F., *On the experimental investigation of memory*, P. R., V, 1898, 477.

Kentor, J. R., *A functional interpretation of human instincts*, P. R., XXVII, 1920, 50.

King, I., *Relationship of abilities in certain mental tests to abilities estimated by teachers*, S. and S., V, 1917, 204.

King, I. and Homan, J. B., *Logical memory and school grades*, J. E. P., IX, 1918, 262.

Kirkpatrick, E. A., *An experimental study of memory*, P. R., I, 1894, 602.

An experiment in memorising vs. incidental learning, J. E. P., V, 1914, 405.

Kline, L. W., *Some experimental evidence in regard to formal discipline*, J. E. P., V, 1914, 259.

The migratory impulse vs. love of home, A. J. P., 1898-9, 1.

Truancy as related to the migratory instinct, Ped. Sem., V, 1897-8, 381.

Kline, L. W. and Owens, W. A., *Preliminary report of a study in the learning process involving feeling tone, transference and interference*, P. R., XX, 1913, 206.

Krueger, F. and Spearman, C., *Die correlation zwischen verschiedenen geistigen Leistungsfähigkeiten*. Zeit. f. Psych. Bd., XLIV, 1906, 50.

Kuhlman, F., *The place of mental imagery and memory among mental functions*, A. J. P., XVI, 1905, 337.

Lakenan, M. E., *The whole and part methods of memorising poetry and prose*, J. E. P., IV, 1913, 189.

Lashly, K. S., *Studies of cerebral function in learning*, Psychobiology, II, 1920, 55.

Lee, F. S., *The nature of fatigue*, P. S. M., LXXVI, 1910, 182.

Leuba, J. H. and Hyde, W., *An experiment in learning to make hand-movements*, P. R., XII, 1905, 351.

Lyons, C. K., *The doctrine of formal discipline*, Ped. Sem., XXI, 1914, 343.

Lyon, D. O., *The relation of quickness of learning to retentiveness*, Arch. of Psych., No. 34, 1916.

Memory and the learning process, 1917.

McCall, W. A., *Correlation of some psychological and educational measurements*, 1916.

Also article same title, S. and S., V, 1917, 24.

McDougal, W., *On a new method for the study of concurrent mental operations and of mental fatigue*, B. J. P., I, 1905, 435.

Marsh, H. D., *The diurnal course of efficiency*, 1906.

Martin, L. J., *The training of emotions*, 1918.

Miles. W. R., *A study in the correlation of elementary and high school grades*, J. E. P., I, 1910, 537.

Mosso, A., *Fatigue*, Eng. Tr., 1904.

Mulhall, E. F., *Tests of the memories of school children*, J. E. P., VII, 1917, 294.

Münsterberg, H.. and Bigham. J., *Memory*. P. R., I, 1894, 34.

Murphy, H. H., *Distribution of practice periods in learning*, J. E. P., VII, 1916, 150.

Myers, G. C., *A comparative study of recognition and recall*, P. R., XXI, 1914, 442.

Recall in relation to retention, J. E. P., V, 1914, 119.

Confusion in recall, J. E. P., VIII, 1917, 166.

Norsworthy, N., *Acquisition as related to retention*, J. E. P., III, 1912, 214.

Offner, M., *Mental Fatigue*, Eng. Tr., 1911.
Ordahl, L. E., *Consciousness in relation to learning*, A. J. P., XXII, 1911, 154.
Rivalry; its genetic development and pedagogy, Ped. Sem., XV, 1908, 492.
Otis, A. S., *Do we think in words?*, P. R., XXVII, 1920, 399.
Painter, W. S., *Efficiency in mental multiplication under extreme fatigue*, J. E. P., VII, 1916, 25.
Patterson, T. L., *Pedogogical suggestions from memory tests*, J. E. P., IX, 1918, 497.
Pechstein, L. A., *Alleged elements of waste, in learning a motor problem by the "part" method*, J. E. P., VIII, 1917, 303.
Whole vs. part methods in learning nonsensical syllables, J. E. P., IX, 1918, 381.
Perkins, N. L., *The value of distributed repetitions in rote learning*, B. J. P., VII, 1914, 253.
Peters, C. C., *The influence of speed drills upon the rate and the effectiveness of silent reading*, J. E. P., VIII, 1917, 350.
Peterson, J., *The effect of attitude on immediate and delayed repetition*, J. E. P., VII, 1916, 523.
Peterson, A., *Correlation of certain mental tests in normal school students*, P. R., XV, 1908, 323.
Phillips, F. M., *A comparison of the work done in successive minutes of a ten-minute practice period in the fundamentals of arithmetic*, J. E. P., VII, 1916, 271.
Phillips, F. M., *Value of daily drill in arithmetic*, J. E. P., IV, 1913, 159.
Poffenberger, A. T., *The influence of improvement in one mental process upon other related processes*, J. E. P., VI, 1915, 459.
Poffenberger, A. T. and Tallman, G. G., *Variability in performance during brief periods of work*, P. R., XXII, 1915, 371.
Pohlmann, A., *Experimentelle Beiträge zur Lehre vom Gedächtnis*. 1906.
Potwin, E. B., *Study of early memories*, P. R., VIII, 1901, 596.
Pyle, W. H., *Retention as related to repetition*, J. E. P., II, 1911, 311.
Economical Learning, J. E. P., IV, 1913, 148.
Concentrated vs. distributed practice, J. E. P., V, 1914, 247.
Standards of mental efficiency, J. E. P., IV, 1913, 61.
and Snyder,
The most economical unit for committing to memory, J. E. P., II, 1911, 133.
Is learning capacity constant for different types of material?, J. E. P., X, 1919, 121.
A study of the mental and physical characteristics of the Chinese, S. and S., VIII, 1918, 264.
Pyle, W. H. and Collings, P. E., *The mental and physical development of rural children*, S. and S., VIII, 1918, 534.
Ruediger, W. C., *The indirect improvement of mental functions through ideals*, Ed. Rev., XXXVI, 1908, 364.

Ruger, H. A., *The psychology of efficiency*, Arch. of Psych., No. 15, 1910.

Reed, H. B., *A repetition of Ebert and Meumann's practice experiment in memory*, J. Exp. Psych., II, 1917, 315.

Race, H. V., *A study of a class of children of superior intelligence*, J. E. P., IX, 1918, 91.

Rich, G. J., *Directed attention and learning*, J. E. P., VIII, 1917, 239.

Richardson, R. F., *The psychology and pedagogy of anger*, Ed. Psych. Mon. No. 19, 1918.

Rietz, H. L., *On the correlation of the marks of students in mathematics, and in law*, J. E. P., VII, 1916, 87.

Root, W. T., *A study of mental fatigue with a group of five boys*, J. E. P., VII, 1916, 533.

Ruckmich, C. O., *The psychology of piano instruction*, J. E. P., V, 1914, 185.

Rugg, H. O., *The experimental determination of mental discipline in school studies*, 1916.

Seashore, C. E. and Kent, G. H., *Periodicity and progressive change in continuous mental work*, P. R., Mon. Sup., VI, No. 28, 1905.

Shaw, J. C., *A test of memory in school children*, Ped. Sem., IV, 1896, 61.

Simpson, B. R., *Correlations of mental abilities*, T. C. Cont. to Ed., No. 53, 1912.

Sleight, G. W., *Memory and formal discipline*, B. J. P., IV, 1911, 386.

Smith, W. G., *The place of repetition in memory*, P. R., III, 1896, 21.

Smith, F. O., *The effect of training in pitch discrimination*, P. R. Mon., No. 69.

Smith, M. and McDougal, W., *Some experiments in learning and retention*, B. J. P., X, 1920, 199.

Smith, T. L., *On muscular memory*, A. J. P., VII, 1896, 453.

Smith, M., *A contribution to the study of fatigue*, B. J. P., VIII, 1916, 327.

Snoddy, G. S., *An experimental analysis of a case of trial and error learning in the human subject*, P. Mon., No. 124, 1920.

Spearman, C., *General intelligence objectively determined and measured*, A. J. P., XV, 1904, 201.

Manifold sub-theories of the "two factors", P. R., XXVII, 1920, 159.

Starch, D., *Transfer of training in arithmetical operations*, J. E. P., II, 1911, 306.

Periods of work in learning, J. E. P., III, 1912, 209.

Correlations among abilities in school studies, J. E. P., IV, 1913, 411.

Starch, D. and Ash, I. E., *The mental work curve*, P. R., XXIV, 1917, 391.

Stetson, G. R., *Some memory tests of whites and blacks*, P. R., IV, 1897, 285.

Stickland, G. I., *The influence of practice in the correlation of abilities*, J. E. P., IX, 1918, 393.

Strong, E. K., *The effect of time interval upon recognition memory*, P. R., XX, 1913, 339.

Two factors which influence economical learning, Journal of Philosophy and Scientific Method, XI, No. 5, 1914.

The effect of length of series upon recognition memory, P. R., XIX, 1912, 447.

An interesting sex difference, Ped. Sem., XXII, 1915, 521.

Swift, E. J., *Studies in the psychology and physiology of learning*, A. J. P., XIV, 1903, 201.

Memory of a complex skillful act, A. J. P., XVI., 1905, 131.

Talbot, E. B., *An attempt to train the visual memory*, A. J. P., VIII, 1897, 414.

Terman, L. M. and Hocking, A., *The sleep of school children, its distribution according to age and its relation to physical and mental efficiency*, J. E. P., IV, 1913, 138, 199, 269.

Thompson, G. H., *A hierarchy without a general factor*, B. J. P., VIII., 1916, 271.

Thorndike, E. L., *Mental fatigue*, P. R., VII, 1900, 466, 547.

Memory for paired associates, P. R., XV, 1908, 122.

The effect of practice in the case of a purely intellectual function, A. J. P., XIX, 1908, 374.

The relation between memory for words and memory for numbers, and the relation between memory over short and memory over long intervals, A. J. P., XXI, 1910, 487.

Practice in the case of addition, A. J. P., XXI, 1910, 483.

Mental Fatigue, J. E. P., II, 1911, 61.

The curve of work, P. R., XIX, 1912, 165.

Repetition vs. recall in memorising vocabularies, J. E. P., V, 1914, 596.

Notes on practice. improvability, and the curve of work. A. J. P., XXVII, 1916, 550.

The effect of continuous exercise and of rest upon different mental multiplication, J. E. P., V, 1914, 597.

Fatigue in a complex function, P. R., XXI, 1914, 402.

and Lay, W. and Dean, P. R., *The Relation of accuracy in sensory discrimination to general intelligence*, A.J.P., XX, 1909, 364.

and Woodworth, R. S., *The influence of improvement in one mental function upon the efficiency of other functions.* P. R., VIII, 1901, 247, 384, 553.

Tolman, E. C., *Retroactive inhibition as affected by conditions of learning*, P. Mon., No. 107, 1917.

Instinct and Purpose, P. R., XXVII, 1920, 217.

Wallin, J. E. W., *Two neglected instances of the transfer of training*, J. E. P., I, 1910, 168.

Has the drill become obsolescent?, J. E. P., I, 1910, 200.

Washburn, M. F., *The effect of the interval between repetition on the speed of learning a series of movements*, A. J. P., XXIV, 1913, 580.

The effect of mental type on the interference of motor habits, A. J. P., XX, 1909, 282.

Watkins, S. H., *Immediate memory and its evaluation*, B. J. P., VII, 1914-15, 319.

Weglin. D. E., *Correlation of abilities of high school pupils*. 1917.

Wells, F. L., *Normal performance in the tapping test before and during practice, with special reference to fatigue phenomena*, A. J. P., XIX, 1908, 437.

The relation of practice to individual differences, A. J. P., XXIII, 1912, 75.

Practice and the work curve, A. J. P., XXIV, 1913, 35.

Practice effects of free association, A. J. P., XXII, 1911, 1.

and Henmon, V. A. C., *Concerning individual differences in reaction time*. P. R., XXI, 1914, 153.

Whipple, G. M. and Curtis, J. N., *Preliminary investigation of skimming in reading*, J. E. P., VIII, 1917, 333.

Whitehead, L. G., *A study of visual and aural memory processes*, P. R., III, 1896, 258.

Whitley, M. T., *An empirical study of certain tests for individual differences*, Arch. of Psych., No. 19, 1911.

Wimms, J. H., *The relative effects of fatigue and practice produced by different kinds of mental work*, B. J. P., II, 1907, 153.

Winch, W. H., *Mental adaptation during the school day as measured by arithmetical reasoning*, J. E. P., IV, 1913, 17.

Some measurements of mental fatigue in adolescent pupils in evening schools, J. E. P., I, 1910, 13, 83.

Mental fatigue in day school children as measured by immediate memory, J. E. P., III, 1912, 18, 75.

Mental fatigue in day school children as measured by arithmetical reasoning, B. J. P., IV, 1911, 315.

The transfer of improvement in memory in school children, B. J. P., III, 1910, 386.

Additional researches on learning to spell—transfer and direct vs. indirect methods, J. E. P., VII, 1916, 93.

Further work on numerical accuracy in school children. Does improvement in numerical accuracy transfer?, J. E. P., II, 1911, 262.

The transference of improvement in memory of school children. B. J. P., II, 1908, 284.

Immediate memory in school children, B. J. P., I, 1904, 127; II, 1906, 52.

Some relations between substance memory and productive imagination in school children, B. J. P., 1911, 95.

Wissler, C., *The correlation of mental and physical tests*, P. R. Mon. Sup., No. 16, 1901, 62.

Woodrow, H., *Practice and transference in normal and feeble-minded children*, J. E. P., VIII, 1917, 85, 151.

Wright, W. R., *Some effects of incentives on work and fatigue*, P. R., XIII, 1906, 23.

Wyatt, S., *The quantitive investigation of higher mental processes*, B. J. P., VI, 1913, 109.

Yoakum, C. S. and Calfee, M., *An analysis of the mirror drawing experiment*, J. E. P., IV, 1913, 283.

An experimental study of fatigue, P. R., Mon. Sup., No. 46, 1909.

INDEX